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ANIMAL ECOLOGY OF AN ILLINOIS ELM-MAPLE FOREST

WITH 7 PLATES AND 15 TABLES

BY

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INTRODUCTION

Quantitative methods have been applied but little to the study of animal communities on land, although the quantitative study of life in the sea has, particularly in the hands of the Danish oceanographers, yielded rich results. Among the most important contributions dealing with animal populations on land are the papers of McAtee (1907), Beebe (1916) and Wolcott (1918), all of whom studied definite limited areas. Of these papers, only that of Wolcott dealt in any way with the successional phases of the problem. The problems of stratification and migration were attacked by Sanders and Shelford (1922) with reference to a pine-dune community. This study covered a period of about two months.

The writer has attempted to investigate quantitatively the animal population of the elm-maple association as represented in a forest in the "savanna" region of Illinois, during an entire year, with supplementary observations covering a greater period of time. During this time a series of meteorological observations was carried out covering as many as possible of the environmental conditions of the habitat, and an attempt was made to correlate the fluctuations in the animal population with changes in environmental conditions. A characterization of the seasonal and stratal communities within the association became possible on the basis of the information gained by the above investigations. Correlated experiments on the reactions of animals in gradients of the environmental factors thought likely to be effective in stratification, and the effect of environmental factors on the rate of development of characteristic species were also carried out.

The present paper gives the results of the above investigations in the following order: (a) a study of the animal population as a whole by the method of random sampling, (b) a study of the stratal and seasonal abundance of certain species prominent in the population, with especial reference to migration, (c) a study and characterization of the communities of the forest, with especial reference to the seasonal succession, (d) the reactions of animals in gradients, (e) experiments on the effect of environmental factors on the rate of development of a spider, *Acrosoma rugosa* and its parasite, *Arachnophaga picea* and (f) a record of environmental conditions in the habitat.

THE HABITAT

The area studied is some sixty acres in extent, located about five miles northeast of the campus of the University of Illinois, and known as "University Woods," the botanical, zoological and entomological reserve of the University of Illinois. The 700-foot and 690-foot contour lines pass through the tract. The drainage is poor, so that in wet seasons the soil becomes saturated with moisture, and water may stand for some time in the Spring in depressions even in the higher parts of the woods. The soil is yellow-gray silt loam, an upland timber soil whose limits are but little beyond the present border of the woods to the north and east. (Hopkins, et. al. 1918). McDougall (1922) has fully described the plant community of this forest. The higher parts are well wooded with a stand composed almost purely of maple (*Acer saccharum*) while a mixed stand of maple and elm (*Ulmus americana*) occupies the intermediate levels and elm is the dominant tree on the lower ground. Other prominent trees are, in order of abundance, *Fraxinus americana*, *F. quadrangulata*, *Tilia americana* and *Carpinus caroliniana*. Many others, such as *Aesculus glabra*, *Quercus rubra*, etc., are present in smaller numbers, and in the more open situations there is a considerable growth of underbrush, largely *Benzoin melissaefolium* and *Asimina triloba*, with seedlings of the various trees comprising the forest.

The tract was for some time rather heavily pastured and some cutting of hardwoods (especially *Juglans nigra*) of which the stumps remain, had been done, but since its acquirement by the University of Illinois some five years previous to the present study, it has been left practically undisturbed. Accordingly reproduction of the woody plants is taking place to a considerable degree.

This area is one of the few remaining bits of the woodland which originally extended into the prairie of central Illinois along the Vermillion River and its tributaries, and like all other similar tracts it has been profoundly modified by the activities of civilized man. The first modification was, doubtless, the elimination of the larger mammals frequenting the deciduous forest under primitive conditions. The clearing for agricultural purposes of the greater part of the former wooded area limited the migration of species restricted to the dense woods, so that when a species lost its hold, for some reason, on a particular area, it was not replaced even on the return of favorable conditions. It is probable that the period of heavy grazing drove from this particular area many forms which have been unable

to return even though the conditions are now favorable for them, because of the isolation of the tract and the absence of suitable migration paths. No characteristic mammals, with the exception of the wood mouse (*Peromyscus leucopus noveboracensis* (Fischer), are present in any number. Even squirrels of all kinds are rare.

The utilization of the neighboring lands for agriculture has led to the incurrence of many introduced forms, especially among those which may be classed as garden and orchard pests. Although, as will be seen above, the conditions studied here do not represent exactly the primitive conditions of the Illinois elm-maple forest, they represent the closest approximation available for study at the present time.

In order to determine the physical conditions prevailing in the habitat under consideration and to determine the character of the climatic rhythm to which the animals living there are subject, it was necessary that an extensive series of meteorological observations* be made. The observations were made at stations as near as possible to the places at which the population samples were obtained and covered the period from July 1, 1921, to July 1, 1922. Salient features are illustrated in figures 6 and 7. A summary follows:

During the summer months the mean daily temperature in the elm-maple forest increases upward from the ground level at the rate of approximately 0.35° C. per ten meters, and relative humidity decreases 3.5 per cent in the same distance. These gradients may be absent or reversed during early morning hours, and during the colder months of the year (Fig. 2, Tables A, B, C, D, E).

The evaporating power of the air is least at ground level, averaging for the period of observation 5.96cc. mean daily evaporation from a standard porous cup atmometer, and increases upward, at first rapidly and then more slowly to a maximum of 15.71cc. at the level of the tops of the trees (Fig. 2, Table F).

The intensity of light in the forest increases rapidly from the ground level up. At noon of a sunny day the intensity at ground level under herbage is about 0.35 per cent of full sunlight, while that at 1.25 m. is about three times as great (Table G).

* A detailed account of methods and results is given in the summary of meteorological observations.

THE ANIMAL POPULATION

Throughout the period of study random samples were taken periodically from the shrub, herb, and ground strata of the forest. Obvious difficulties prevented random sampling from the tree stratum. Because of the leaves on the surface of the soil, the ground stratum was divided into two parts, referred to as the leaf and soil strata. Of the latter only the upper 10 cm were considered.

The unit sample from the soil and leaf strata was taken from an area 2 ft. (0.61 m) square. Leaves and other debris from this area were gathered and placed in fine wire screen boxes, the contents of which were sorted in the laboratory after the animals had been quieted by the use of ether. After the leaves had been removed the soil of the bared area was carefully gone over to a depth of 10 cm and all animals obtained placed in vials for further assortment.

The unit sample from the herb and shrub strata was that obtained by ten short sweeps through the vegetation with an insect net whose subcircular opening averaged 30 cm in diameter. The contents of the net were transferred to screen cylinders and taken to the laboratory for further examination.

The method of collection was probably most efficient in the leaf stratum, the soil stratum and the herb and shrub strata following in the order named. Assuming the average depth of the herb stratum to be 0.5 m and the average length of the sweep of the net to be 1.0 m, calculation shows that ten such sweeps include approximately the volume of vegetation above the unit area. The foliage of the shrub stratum may also be assumed to be of approximately the same depth, although the relative efficiency of the sampling method is somewhat less in this stratum. All collections were made near the stations from which the meteorological data were obtained, and samples at the various levels were, in general, taken within a few minutes. In the tables and the text all collections are dated according to the last day of the week in which the collection was made, reckoning from Monday to Monday. This day was chosen because the hygrograph and thermograph sheets were changed at this time, and means of climatic factors could be computed most easily sheet by sheet.

The numerical data obtained from samples taken in the manner described above are given in Table H and the relations are illustrated graphically in Figure 1, A. In the curve representing the total population in all strata, we find a drop in the fourth week (the week of July 25) correspond-

ing to an increase in the evaporating power of the air (See Figure 2, G-L). At the beginning of the period of study, the woods were dry, due to a long period of heat and drouth during June, and the animal population was already small. Sanders and Shelford (1922) found an increase of population with drouth and high temperature in a pine-dune community. With the increase in moisture content of the air (and of the soil-leaf strata) during the following weeks, there was a marked increase in the size of the collections, and the great increase culminating in the high maximum during the fourteenth week (ending October 3) might seem to be due to this cause. A gradual decline in temperature (Figure 2, C) had been going on, however, with a considerable increase in mean variability (Figure 2, E) due to lower temperatures at night, so that, while the initial increase was due to a return to moisture conditions more nearly optimum for the species concerned, the sudden and great increase was due almost entirely to the autumnal migration toward place of hibernation. An analysis showed that the maximum was caused almost entirely by a few genera of beetles and two genera of Cicadellidae, chiefly hibernating species in course of migration from the forest margin to the leaf stratum of the more protected portion of the woods. Following the maximum, the fall was rapid, as temperatures continued to fall (the first heavy frost occurred the night of October 4), stimulating the insects to seek more complete shelter. The peaks in the totals curve during the winter months after November 13, the date of the first ice formation, were caused by samples taken on warm days when insects partially emerged from hibernation, or at least, approached near enough to the surface of the soil or leaf strata to be collected. The striking population increases of spring began about April 10, reaching high maxima on May 1 and May 8. The great numbers on these dates were principally a forest margin beetle, *Epitrix brevis*, and a bug *Corythucha aesculi* which inhabits the tree stratum. As these insects passed on to their summer habitats, the population of the lower strata again decreased sharply. The determining factors of the sudden appearance of great numbers of these insects could not be definitely determined. Increase of temperature and greater variability, especially in the ground strata were probably of great importance.

The largest numbers, during the summer months, were found in the leaf and herb strata, and, for the most part, the curves (Fig. 1, B D) representing the population of these two layers varied together. Both showed marked minima during the excessively dry week of July 25, and both rose as the weather became more favorable. The leaf stratum as well as the herb stratum exhibited the marked maximum of October 3, due to the influx of hibernating insects. The low point in the leaf stratum curve for October 17 may have been due to the chance selection of a poorly inhabited area. At any rate, after the fall in the herb stratum curve, there was a

second maximum, due evidently to the downward migration of the insects which were, the week before, in the herb stratum. After this date, the decline of the herb stratum curve was very rapid, and the course of the totals curve was almost entirely governed by that of the leaf stratum. The large numbers found in certain of the late winter collections were partly due to the appearance of larvae of forms passing the winter in this state. In the spring the population of the leaf stratum remained greater than that of the herb stratum until after April 10, which marked the first appearance of abundant vernal herbage. The maximum at the latter level was reached May 8, the most abundant insect being *Epitrix brevis*. An equally rapid fall in numbers followed the rapid migration of this species.

The shrub stratum (Fig. 1,C) showed, in general, variations in population paralleling those of the strata below. It is of interest, however, to note that the autumn maximum in this stratum came a week earlier than that of the herb stratum. The collection of this date, also, was the only one showing a larger population in the shrub than in the herb stratum. This relation was due to the fact that the insects of the forest margin first migrated inward at the level of their summer occurrence, later migrating downward for hibernation. The spring maximum of the shrub stratum, due largely to the upward migration of *Corythucha aesculi*, occurred on May 1.

The most striking phenomena of the entire period covered by the collections were the hibernating reaction of the autumn, involving a migration inward from the forest margin and downward to the forest floor, and the migration in the opposite sense in the spring. The principal inciting factors of the former seemed to be the fall in temperature and the great daily range of temperature of the early autumnal period. The latter was likewise a response to the changing temperature conditions of the forest, supplemented, perhaps, by changing moisture and light conditions. The fact that many species react alike and at the same time to the same stimulus or combination of stimuli shows a great degree of similar adjustment to the climatic rhythm of the temperate savanna on the part of the characteristic insects of the region.

DOMINANT SPECIES

Certain species which were present in the samples over a considerable period of time, or abundantly for a shorter period, were chosen for further study from the standpoint of seasonal succession. The animals chosen were spiders, Hemiptera and Coleoptera, because of the greater abundance and more conspicuous character of these groups. Data as to seasonal succession and seasonal variations in abundance of these species may be best visualized by reference to figures 3, 4 and 5.

Migratory Forms

Notoxus monodon Fab. [Figure 3B]

This beetle (*Anthicidae*) was first taken from the herb stratum August 29, the maximum at this level being reached during the week of October 3. It is a forest margin species hibernating in the forest, and its early appearance on forest herbage represents the first step in this migration. Very large numbers were found among leaves on the ground October 31, and during the entire winter, on warm days, especially, considerable numbers were taken from this stratum. A second maximum corresponding to the spring migration occurred on April 3, and on April 10 small numbers were again found in the herb stratum.

Telephanus velox Hald. [Figure 3E]

This beetle (*Cucujidae*) was found on herbage October 3, and thereafter throughout the winter in the leaf stratum. The autumn maximum was on November 7 and the spring maximum on April 10.

Phalacrus politus Melsh. [Figure 3C]

Included in the chart are other Phalacridae as well as *Phalacrus politus*, to which species most of those taken belonged. They were among the most abundant beetles found after September 26, when they were observed in the samples from all three strata. The numbers from the shrub stratum were small, however, and none were taken from this level after October 31. The maximum in the herb stratum came October 3, and on this date, also, was the first maximum for this family in the leaf stratum. A second maximum appeared on November 7. The week ending November 7 was characterized by three fairly heavy frosts, and a marked general fall of temperature. The first maximum, on October 3, followed a period of falling temperature, and great variation between night and day, without any actual frost, while the maximum in the leaf stratum followed a similar period with considerably lower temperature. *P. politus* is a forest margin species and its presence in the denser forest was an indication of a hibernation migration. The species was found throughout the winter in the leaf stratum. In the spring these beetles began to be taken in considerable numbers from this stratum on March 27, the maximum here being reached May 8, and in the upper strata on May 15. Thus the vernal migration is shown to follow the route taken in the autumn, in inverse order.

Glyptina spuria Lec. [Figure 3F]

This Chrysomelid was found in the shrub stratum from September 5 to November 7, and after that date in the leaf stratum. A few individuals were also swept from the herb stratum on November 21, which was a comparatively warm and sunny day. The summer habitat of this species is the forest border and roadside, and its appearance in the forest collections

is due to its hibernating reactions. Individuals were found throughout the winter, especially on warm days. In the spring very large numbers were found in the shrub and herb strata. They were found first in the herb stratum on March 13 and in the shrub stratum on April 24, but the maximum for both strata occurred on May 8.

Epitrix brevis Schw. [Figure 3G]

Enormous numbers of *E. brevis* (Chrysomelidae) were swept from the herb stratum October 3, the first individuals being taken from this level on September 19, and the last, October 17. A few were swept from the shrub stratum during the week of September 26, and a few hibernating individuals were obtained January 16 and 23. The sudden appearance of this beetle represents a migration, *en masse*, in preparation for hibernation. The small numbers taken during the winter are due, evidently, to deep hibernation. Beetles of this size and color would also be difficult to distinguish in soil, so that perhaps some may have escaped notice. In the spring this species appeared in the shrub stratum on April 10, a very high maximum being reached on May 8, after which the decline was rapid. No great numbers appeared at any time in the herb stratum. Evidently no halt is made by *E. brevis* in the lower stratum on the way either to or from the place of hibernation.

Epitrix fuscula Crot. [Figure 3H]

While not found in as large numbers as the other member of the genus, this little beetle was fairly abundant after September 26. None were found elsewhere than in the leaf stratum where hibernation took place. It was found in much larger numbers through the winter than *E. brevis*. This, also, is a forest margin species, feeding principally on plants of the family Solanaceae, near the roots of which the eggs are laid in the spring. According to Somes (1916) there are three broods per year in Missouri.

Chaetocnema confinis Crot. [Figure 3I]

This forest border chrysomelid was first taken from the shrub stratum September 19, becoming abundant on September 26. Thereafter the numbers appearing in the samples decreased. One individual was taken from the leaf stratum November 14, and one from the herb stratum May 8. It is probable that the species hibernates in such situations as not to be found ordinarily by the methods of collection used.

Phyllotreta sinuata Steph. [Figure 3J]

This chrysomelid of the forest border and meadow was found in small numbers on July 18 in the leaf and soil strata, but the real migration did not begin until October 3, culminating in a maximum on October 17. Hibernating individuals were noted in the collections throughout the winter, the number observed increasing with the first warm days of the season.

The principal migration of this beetle took place only after several rather severe frosts.

Longitarsus melanurus Melsh. [Figure 4K]

Although taken from the herb stratum only, the frequency polygon of this beetle (Chrysomelidae) is typically like those of other beetles coming to the forest for hibernation, and it is probable that hibernation took place in situations from which collections were not made. This species is found during the summer in the rank herbage along roadsides and in other similar situations.

Diabrotica vittata Herbst. [Figure 3A]

The striped cucumber beetle is a forest margin beetle which has become a pest by invasion of cultivated fields. Autumn finds many individuals in the forest in preparation for hibernation. The first large collection was from the leaf stratum on September 12. On sunny days later it was swept from shrub and herb strata. Remains of dead beetles found during the winter indicated that the number completing hibernation is probably relatively small. Probably only those in the most protected situations are able to survive. In the spring it was found first in the leaf stratum, then in the herb and shrub strata. The spring maximum was April 24. Mating takes place in early spring on Crataegus and Prunus, typical forest margin trees.

Phytonomus nigrirostris Fab. [Figure 3D]

The lesser clover-leaf weevil seeks its hibernating quarters very early in the season. According to Mr. Faustino Otanes, who made systematic collections on alternate days from a clover field on the experimental farm of the University of Illinois, very few were found there after July 7. They were found, in small numbers, in the woods in the herb and leaf strata from the beginning of the series of collections. None were swept from herbage after September 26. Maximum collections were made from the leaf stratum on September 12 and October 31. The former date followed a week of declining temperatures, which evidently caused greater numbers to seek the protection of the leaf stratum, while the latter date was in a period of rising temperature. Throughout the winter these beetles were found in the leaf stratum in increased numbers on warm, sunny days, indicating a vertical migration according to temperature. *Phytonomus nigrirostris* is an introduced species, coming from Europe, and was first collected in Illinois by Mr. W. P. Flint in 1919.

Empoasca viridescens Walsh. [Figure 5Y]

The leaf-hopper named above was not noted at all until September 19, and appeared in very large numbers on September 26, principally in the herb stratum, but to a lesser extent in the shrub stratum. It was swept

from these strata in very large numbers during a period of about six weeks, the largest numbers occurring on September 26 and October 31. The intervening period was marked by low temperatures, which probably caused the insects to retire to more sheltered locations. Leaf-hoppers are also known to migrate downward to the base of herbage during dry weather, so that the numbers obtained by random sweeping are smaller under such weather conditions. After December 1, no Cicadellidae were found elsewhere than in the leaf stratum and in the soil below. They were more abundant in the collections on warm days when they could be seen moving about on the surface of the leaf layer. They emerge very early in the spring, as soon as food plants are available.

Erythroneura obliqua Say (and varieties). [Figure 5Z]

The frequency curve for this leaf-hopper, in almost all points, is similar to that for the form just discussed. The first maximum occurred a week later and the second maximum was relatively higher. Only a few were found in the herb and shrub strata, and practically all were taken from the leaf stratum. Greater numbers of this species were taken during the winter than of the preceding.

Corimelaena pulicaria (Germ.). [Figure 4M]

As this form (Cydnidae) is of little economic importance, not much is known of its life history. However, it is an insect of the forest border, migrating inward to the more densely wooded areas for hibernation in the autumn, and emerging again in the spring. The frequency polygon is similar in detail to that of *Phalacrus politus* (Fig. 3C).

Lygus pratensis (L.) the tarnished plant bug, and *Blissus leucopteruis* (Say), the chinch bug (Figure 4N aud O), are too well known to require comment. The latter shows well the two periods of abundance although they are somewhat closer together than for most of the other insects studied. Lygus is a forest border form feeding on the forest border trees as well as on herbage. The latter is primarily a grass feeder.

Corythucha aesculi O. & D. [Figure 4L]

This lace-wing (Tingidae) is included among the migratory forms, although the migration in this case is vertical instead of horizontal. It inhabits the tree stratum during the summer. It began to appear in very large numbers in the shrub stratum on April 24, reaching a maximum a week later. This coincided with the first abundance of vegetation in this stratum, and with the development of the tree foliage these insects spread to the higher levels, their abundance at the shrub level rapidly falling off. A few individuals had been found, throughout the autumn and winter, in hibernation in the leaf and ground strata. Corythucha winters, generally, in the adult form, depositing the eggs in early spring, but may also winter in the egg stage.

The large numbers of beetles and other insects in the late summer and autumn collections were mostly due, not to species feeding and breeding in the forest, but to forest border and prairie species which migrate forestward in preparation for hibernation. Many of the leaf-beetles belonging to the forest proper also hibernate, but in no case were the numbers taken in random sampling sufficiently large to warrant the construction of frequency polygons illustrating their relative abundance. The question of how far into a larger forest species such as these would penetrate for hibernation is unanswered. It is probable that the distance would vary with different species, but the tract of woodland studied was too small to afford a solution of this problem.

In most of the species considered the stimulus initiating migration was apparently the gradual increase, in early autumn, in the daily range of temperature, caused by lower night temperatures. Some species required the additional stimulus of a frost of greater or less intensity, while others which appeared in the forest very early did not require this stimulus. The disappearance or maturation of the food plant may have been a factor in some cases. The majority of the insects appeared in maximum numbers between September 26 and October 3, a period characterized by falling temperatures and a marked drop in the night minimum.

In the forest, the insects appeared first in large numbers in the stratum corresponding to that in which the summer portion of their life history was spent. Insects whose principal summer food plant is in the high forest margin, first appeared in the shrub stratum. Those whose summer habitat is the low forest margin or meadow, first appeared in the herb stratum. A downward migration followed under the stimulus of an additional fall in temperature. Insects from the shrub stratum, in most cases, spent a short period of time in the intermediate herb stratum before seeking the final place of hibernation in the leaf or soil strata. Warm days reversed the course of migration, and even in winter, high temperatures brought hibernating insects nearer to the surface, so that they were taken in greater numbers. Many species showed spring maxima also, due to the breaking up of hibernation. These occurred uniformly shortly after the first definite spring rise in temperature and the appearance of vernal herbage.

Non-Migratory Forms

Uloborus americanus Walck. [Figure 42]

The frequency polygon illustrating the occurrence of this spider is in two parts, the heavy line representing the adults and the light line the juveniles. Adults, at first more abundant than the young, disappeared entirely after October 17. The first young were taken August 22, and increased rapidly in numbers until October 17 after which they, also, dis-

appeared from the collections. This species hibernates when half-grown, reaching maturity in early summer. The young emerge from the egg in the latter part of July.

Dictyna [Figure 4S]

Most of the young spiders of this genus probably belonged to the species *volupis*, but were too young for positive identification. The web of this spider is made in the hollow of a slightly rolled leaf, where the eggs are deposited in July. Young and half-grown individuals were abundant August 29, and the largest numbers for the season were taken on October 3. The numbers then declined, and after October 24 none were found except in hibernation in the leaf stratum. As was the case with the insects these spiders were also found on the warm winter days.

Tetragnatha [Figure 5X]

Adults and young of this genus were not found together, as the former appeared in the collections only in the very early part of the season, none at all being found after the second week in July. The young appeared first on October 24, and first became abundant on November 21. The maximum occurred on December 19. These spiders were found almost invariably in the shrub and herb strata, very few being found in the lower strata even during the very cold weather. Hibernation, in Tetragnatha, simply means seeking a somewhat sheltered place in a crevice in the bark or some similar location, for a few hours or days when weather conditions are very unfavorable. As soon as the air becomes slightly warmer, the spiders emerge and again become active.

Epeira gibberosa Hentz. [Figure 5W]

This widely distributed species was the most abundant spider during the later summer months, reaching a maximum during the week of August 29. None were found after November 7. This species does not hibernate in the adult stage, but eggs are deposited during the early autumn.

Cocoons of this species are formed from the small folded leaves of shrubs, the petioles of which are reenforced by strands of silk and which are lined and fastened together at the edges with silk. These cocoons became very numerous after October 15. One other unknown species forms similar cocoons, generally in larger leaves and at a greater height from the ground. The eggs hatch within a month or so after deposition, and the young pass the winter in the cocoon, to emerge in the spring. Experiments indicate that there is a period of dormancy after the emergence from the egg of the young spider, and that, although favorable conditions may bring about emergence from the cocoon of spiders which have not been subjected to prolonged low temperatures, those which have experienced such temperatures emerge more quickly upon the return of favorable conditions.

The cocoons are very heavily parasitized by a hymenopterous insect, *Arachnophaga picea* Riley. Of 52 cocoons examined on January 9, 22 were found to have been parasitized by some organism which had already emerged, and four were found to contain hymenopterous larvae, of which there were, in each case, two. Of 350 cocoons used in experiments, 47 produced from one to five individuals of *A. picea*. In the greater number of cases, there were two insects, one male and one female, in each cocoon. Single individuals of each of two other species also emerged from other cocoons of the same lot.

Acrosoma rugosa Hentz. [Figure 5V]

This conspicuous spider was very much in evidence during the late summer, particularly in more shady situations. Only a single male was taken on July 11. While the females must have been as abundant at this time as later they did not reach their greatest prominence until the end of August. After this the numbers decreased rapidly, and the last one was taken October 10. This species does not hibernate in the adult stage, but passes the winter in the egg.

Xysticus elegans Keys. [Figure 4T]

Adults were found in small numbers during the earlier part of the season, the last on October 10. The young were very numerous throughout the summer and the greater part of the winter. Maxima were evident on August 1 and October 17. After the latter date none were found in the herb stratum whence the majority were taken during the summer. A large number also appeared from hibernation on February 20 and 27, after the ground had been warmed by a series of warm days.

Anyphaena rubra Emer. [Figure 4R]

Spiders presumably of this species, mostly immature, were taken throughout the season, the maximum number being recorded for October 17, mostly in the herb and shrub strata prior to November 14, and in the leaf stratum after that date. Adults mature in early summer and hibernation takes place in the half-grown state. Large numbers were taken from rolled leaves during October. An increase in the number of individuals in the collections was noted during the warm weather of the latter part of February.

Dendryphantes aestivalis Emer. [Figure 4P]

The frequency polygon for this species is almost exactly the same, except for a slightly earlier appearance of the young, as that of Uloborus previously discussed. In the latter part of the season, many young were found in rolled leaves, evidently in preparation for hibernation.

Linyphia phrygiana Koch. [Figure 5U]

Young of this species were abundant during the entire summer and autumn. The last to be swept from the shrub stratum were observed on

November 28. A hibernating individual was found in the upper soil layer on December 12, and specimens were again found on low herbage as early as January 9.

The spiders listed above, unlike the insects previously mentioned, are permanent residents of the forest (some are found also outside the forest), instead of forms coming to the forest mainly for purposes of hibernation. In some cases the frequency polygons expressing the relative abundance of certain species of spiders are quite similar to those of the beetles, with the maxima somewhat less abrupt. The rise here, however, was not due to an inward migration of the species but to the growth of the young and, in some cases, to their migration through a relatively short distance to the location in which they were taken. The species having this form of curve are those which spend the hibernation period as approximately half-grown juveniles, and mature early the next year. *Dendryphantes aestivalis*, *Uloborus americanus*, *Anyphaena rubra*, *Dictyna volupis* and *Xysticus elegans* constitute a unit in so far as adjustment to the climatic rhythm of the temperate deciduous forest is concerned, as the differences in their annual cycles are small and relatively unimportant. Another less homogeneous group is exemplified by *Acrosoma rugosa* and *Epeira gibberosa*, which ordinarily spend the winter within the egg case. In these the life cycle is much the same except that the period of dormancy comes earlier in the life of the individual, and the period of maturity comes later in the summer. Tetragnatha and Linyphia belong, loosely, to a third group, differing mainly in the degree of activity during the winter. Tetragnatha seems to show a more rapid rate of development, or perhaps, a more continuous development through the winter, as indicated by the earlier maturity and the later appearance of the young.

ANIMAL COMMUNITIES

The animal communities of a given region cannot be considered, logically, separately from the plant communities. In fact, the division into animal and plant communities is often an entirely arbitrary one, and the dominants of a given community may be plants or animals or partially one and partially the other. It is customary to speak of the larger terrestrial communities, at least, in the terms of plant dominants, to the exclusion of animal dominants. This is partially because of the more obvious nature of the differences in vegetation-form of the climax formations, and partially due to the fact that the plant dominants of the biotic community often exhibit actually a greater degree of dominance than the animals. This is probably true to a much greater degree in forest communities than in those characterized by lower types of vegetation-forms.

In a savanna such as that studied in the present instance there are two distinct types of plant communities, that of the woodland and that of the grassland. The dominant woodland species are in the present instance, *Ulmus americana* and *Acer saccharum*, both characteristic dominants of the Eastern Deciduous Forest Formation. The dominant of the grassland community is, according to Sampson, *Andropogon furcatus*. Clements considers this community as an associes leading here to a deciduous forest climax, and farther west to a true prairie climax (Stipa-Koeleria Association). The plant societies of the Andropogon associes are, for the most part, those of the Stipa-Koeleria association, although there are a few invaders from woodland and thicket. It will be noted that Clements does not recognize a savanna formation as such, but considers the woodland components as approaching the climax of the deciduous forest formation, and the grassland as an associes of a subclimax whose final goal is also (here at least) the deciduous forest. No attempt has been made, in this paper, to study the animal components of the grassland community except in so far as these animals appear as seasonal migrants in the forest. Particular stress has been placed upon the animal components of the forest community.

As stated above, the plant dominants of the woodland community are *Ulmus americana* and *Acer saccharum*. The community may be spoken of as an elm-maple association, whether we consider it as a part of a savanna formation or as a unit in the temperate deciduous forest. This association is more or less distinctly divided into the maple and the elm consociations. The subdominants of the shrub stratum are *Asimina triloba* and *Benzoin*

mellissaefolium. Seasonal societies are in the main absent at this level. In the herb stratum, however, seasonal phases are distinctly marked. McDougall distinguishes the following subdominants of the respective societies:

Prevernal societies
Claytonia virginica
Isopyrum biternatum
Collinsia verna
Dicentra cucullaria
D. canadense
Phlox divaricata
Geranium maculatum
Floerkia proserpinacoides

Vernal societies
Hydrophyllum appendiculatum
H. canadense

Aestival societies
Laportea canadensis
Impatiens biflora
I. pallida

Serotinal and Autumnal societies
Campanula americana
Eupatorium urticaefolium
and other compositae.

The ground strata have not been studied from the botanical standpoint.

DOMINANTS AND SUB-DOMINANTS

The seasonal distribution of some of the principal components of the animal community has been indicated in the preceding section. An attempt will now be made to characterize the seasonal animal societies which correspond more or less in duration to the plant societies just mentioned.

The prevernal period, beginning about the first of March, is characterized by rapidly rising temperatures of both air and soil accompanied by a great deal of rainfall, with a resulting high moisture content of air and soil. As most of the forms present at this time are in or near the soil stratum, the changes in conditions at this level are of the greatest importance.

The animal society of the prevernal period is very inconspicuous as but few of the insects have risen far above their places of hibernation. It is difficult to decide as to dominance at this time but *Phalacrus politus*, *Epurea rufa*, *Epitrix brevis* and *Notoxus monodon*, all hibernating beetles, seem to be most numerous. The spider *Tetragnatha laboriosa* is the only

prominent organism in the herb and shrub strata. *Anyphaena rubra* and *Lycosa rubicunda* (spiders) are found in the leaf stratum with the beetles mentioned above. The spiders are the only subdominants not migratory in character.

The vernal period may be said to begin with the appearance of abundant vernal herbage, about the first of April. There is, at this time, a well-developed plant society of the herb stratum and the leaves are appearing in the shrub stratum, and, somewhat less conspicuously, in the tree stratum. This is a period of conspicuously large population due to the upward and outward migration of insects of the tree stratum and of the forest edge.

The dominants of the vernal society are, if migratory forms may be considered, *Epitrix brevis*, *Glyptina spuria* and *Diabrotica vittata* in the herb stratum, and *Diabrotica vittata* and *Corythucha aesculi* in the shrub stratum. Other species of prominence are *Phalacrus politus* in the herb and shrub strata and *Tetragnatha laboriosa* and *Anyphaena rubra* in the herb stratum. It will be recalled that in the prevernal period Epitrix and Phalacrus were subdominants of the ground stratum. The other forms here mentioned, with the exception of Tetragnatha, were also in the ground stratum during the prevernal period. The same is true of *Xysticus elegans*, *Harpalus erythropus*, *Corimelaena pulicaria* and *Blissus leucopterus* which become subdominants during the vernal period.

The period between June first and September first is divided rather roughly into two parts, the first characterized by rising temperatures and increasing evaporating power of the air, and the second by a reversal of these changes. The former may be called the aestival period and the latter the serotinal. The population of the forest during this time is not nearly as great as during the preceding and following periods due to the absence of migratory forms. It is composed almost entirely of animals remaining in the forest throughout their life cycles.

A considerable number of species persist throughout the entire period. Of these the most prominent in the herb and shrub strata is *Epeira gibberosa*. Several other spiders including *Xysticus elegans*, now in the herb and shrub strata as well as below, *Pisaura undata* in the herb stratum, and *Acrosoma rugosa* in the shrub stratum, are found in sufficient numbers to entitle them to rank as subdominants. A few flies, such as *Sympycnus lineatus*, *Sapromyza fraterna* and *Minettia lupulina* are fairly abundant in the herb stratum but not as subdominants. Ants, *Camponotus herculeanus pennsylvanicus*, *Formica fusca*, *Lasius niger americanus*, and *Ponera coarctata pennsylvanica*, are sufficiently numerous to be considered as subdominants of the ground strata. The aestival period is also characterized by a large number of flies not taken at other times of the year. Among these are *Tipula mingwe*, *T. flavoumbrosa*, *Sapromyza notata*, *Psilopus tener* and *Dolichopus scapularis*.

During the serotinal period many additional forms appear, prominent among which are the lantern flies *Acanalonia conica*, *Ormenis pruinosa* and *O. septentrionalis* in the herb stratum. Here also appear *Linyphia phrygiana*, *Anyphaena rubra*, and *Dendryphantes aestivalis* which are about equally distributed in the herb and shrub strata, and a few other spiders. Other species present at this time are the flies *Sapromyza fraterna*, and *Psilopus scintillans* in the herb stratum, the beetles *Epurea rufa* in the leaf stratum and *Phytonomus nigrirostris* in the leaf and herb strata. The last named is an early migrant from the clover fields. None of those just mentioned are present in sufficient numbers to be considered sub-dominant but there is a sufficient differentiation between the make-up of the community during the earlier and later parts of the summer to warrant a distinction between the two phases of the summer society.

The meteorological characteristics of the autumnal period and their relations to the inward and downward moments of the migratory forms have been discussed at length in the section on the census of the animal population. The autumnal society is again dominated by the species migrating to the woodland for hibernation, and those animals which pass their entire life history in the forest are obscured by the migrants. The principal subdominants are the beetles *Phalacrus politus*, *Epitrix brevis*, *Notoxus monodon*, and *Telephanus velox*, and the leaf-hoppers *Empoasca viridescens* and *Erythroneura obliqua*. Phalacrus, Epitrix and the leaf-hoppers are found first in the shrub stratum, and thereafter in the herb and leaf strata. Notoxus and Telephanus are found first in the herb stratum and then in the leaves. A discussion, with especial reference to migration, of these species and others occupying somewhat less prominent places in the community, has already been given and the reader is referred to that section of the paper for further information in regard to the constitution and stratification of the autumnal society.

The animals spending the winter portion of their life cycles in the elm-maple association might be considered as making up an additional society, the hibernal. While none of these forms exhibit any great degree of activity, many become active on warm days, especially. The dominants of the winter period are the Hemiptera *Empoasca viridescens*, *Erythroneura obliqua*, *Blissus leucopterus*, *Lygus pratensis*, and *Corimelaena pulicaria*, the beetles *Phalacrus politus*, *Telephanus velox*, *Epitrix fuscula*, and *Notoxus monodon*, the fly *Leptocera evanescens* and the spiders *Xysticus elegans*, *Tetragnatha laboriosa* and *Anyphaena rubra*. All of these are found in the ground stratum, particularly under the shelter of the layer of fallen leaves, with the exception of Tetragnatha, which is found in the herb and shrub strata.

The animal communities of the elm-maple forest are characterized by great seasonal variation. As far as the lower strata, at least, are concerned, the changing composition of the seasonal societies obscures the vertical

stratification. As mentioned previously, the same forms may appear successively in all three of the strata, and the same organism may be, at different seasons, a subdominant in different strata. This is especially true of the forms which migrate to and from the forest edge. A summary of the seasonal and stratal societies is given below:

Shrub Stratum	Herb Stratum	Ground Stratum
Prevernal Societies		
Tetragnatha laboriosa	*Tetragnatha laboriosa*	*Phalacrus politus*
		Epurea rufa
		Epitrix brevis
		Notoxus monodon
		Erythroneura obliqua
		Xysticus elegans
Vernal Societies		
Corythucha aesculi	*Epitrix brevis*	*Harpalus erythropus*
Diabrotica vittata	*Glyptina spuria*	*Corimelaena pulicaria*
	Diabrotica vittata	
Aestival Societies		
Epeira gibberosa	*Epeira gibberosa*	*Xysticus elegans*
Xysticus elegans	*Xysticus elegans*	*Camponotus herculeanus*
Acrosoma rugosa	*Pisaura undata*	*Formica fusca*
		Lasius niger
Serotinal Societies (In addition to above)		
	Acanalonia conica	
	Ormenis pruinosa	
	Ormenis septentrionalis	
Autumnal Societies		
Phalacrus politus →	*Phalacrus politus* →	*Phalacrus politus*
Epitrix brevis →	*Epitrix brevis* →	*Epitrix brevis*
Empoasca viridescens →	*Empoasca viridescens* →	*Empoasca viridescens*
Erythroneura obliqua →	*Erythroneura obliqua* →	*Erythroneura obliqua*
	Notoxus monodon →	*Notoxus monodon*
	Telephanus velox →	*Telephanus velox*
Hibernal Societies		
Tetragnatha laboriosa	*Tetragnatha laboriosa*	*Empoasca viridescens*
		Erythroneura obliqua
		Blissus leucopterus
		Lygus pratensis
		Corimelaena pulicaria
		Phalacrus politus
		Telephanus velox
		Epitrix fuscula
		Notoxus monodon
		Leptocera evanescens
		Xysticus elegans
		Anyphaena rubra

A further list of species taken in the forest, including those whose numbers were too small for mention among the dominants is given below. All forms are listed according to the stratum in which they were found.

List of Species Taken in University Woods. July 1, 1921 to July 1, 1922, with dates.

GROUND STRATUM

Diptera

Agromyza sp? larva (Agromyzidae) (Nov. 14).
Bibio albipennis Say, larva (Bibionidae) (Oct. 31; Nov. 21; Dec. 19).
Atrichopogon sp. undescribed (Chironomidae—Midge) (November 21).
Mycetophila punctata Meig. (Mycetophilidae—Fungus gnat) (November 7, 21; Dec. 19; Jan. 23).
Geosargus virdis Say, larva (Stratiomyidae) (Sept. 19; Oct. 3)
Microchrysa sp? larva (Stratiomyidae) (July 11).
Chionea sp? (Tipulidae—Wingless crane-fly) (Nov. 14).

Hemiptera

Catarhintha mendica Stål (Coreidae) (Oct. 3).
Corimelaena pulicaria Germ. (Cydnidae—Burrower-bug) (July 11; Aug. 22; Oct. 3, 17; Nov. 7, 14, 21, 28; Dec. 19; Jan. 2, 9, 16, 23, 30; Feb. 6; Mar. 27; April 3, 10, 17, 24; May 1, 8).
Aphanus umbrosus (Dist.) (Lygaeidae) (Sept. 12).
Blissus leucopterus (Say) (Lygaeidae—Chinch-bug) (Sept. 12; Oct. 3, 17, 31; Nov. 7, 14, 21; Dec. 5, 12, 19; Jan. 2, 9; Feb. 6; Mar. 27; April 24; May 8).
Nabis annulatus Reut. (Nabidae—Damsel-bug) (July 11, 18).
Euschistus euschistoides (Voll.) (Pentatomidae—Shield-bugs) (Oct. 17; March 27).
Menecles incertus (Say) (Pentatomidae) (July 4, 25; Aug. 1; May 22).
Corythucha ciliata (Say) (Tingidae—Lace-bug) (Oct. 3).
Erythroneura comes var. ziczac Walsh (Cicadellidae—Leaf-hoppers).
Erythroneura obliqua var. noevus Gill (Cicadellidae) (Oct. 31; Nov. 9; Jan. 2, 9, 23; Feb. 6, 20, 27).

Hymenoptera (Formicidae—Ants).

Aphaenogaster fulva Rog. (Aug. 8; Sept. 19; May 29; June 26; July 4).
Camponotus caryae Fitch var? (Aug. 22, 29; Sept. 12, 19; Oct. 3; June 5, 26; July 4).
Camponotus herculeanus pennsylvanicus DeGeer (July 11; Aug. 8; June 12; July 4).
Crematogaster lineolata Say (Sept. 26).
Formica fusca L. (July 4; Aug. 8, 29; June 12, 19, 25).
Lasius niger L. var. americanus Emery (July 4, 25; Aug. 29).
Lasius umbratus mixtus Nyl var. aphidicola Walsh (Nov. 28; June 19).
Myrmica punctiventris Rog. (July 11, 25; Aug. 8, 22, 29; Sept. 12, 19; Oct. 3; April 27; May 15; June 19, 26; July 4).
Myrmica scabrinodis schencki Emery var. emeryana Forel (July 18, 25; Aug. 8, 22, 29; Sept. 12, 26; Oct. 3; Nov. 21; Jan. 2; March 27; June 5; July 4).
Ponera coarctata pennsylvanica (Buckley) Emery (July 11; Aug. 8, 22; Jan. 9; May 8).
Prenolepis imparis Say (Sept. 12).

Coleoptera

Agonoderus pallipes Fab. (Carabidae—Ground Beetles) (Oct. 31).
Anisodactylus baltimorensis Say (Carabidae) (Oct. 31).
Anisodactylus carbonarius Say (Carabidae) (Sept. 19).

Anisodactylus interstitialis Say (Carabidae) (Aug. 1; Sept. 19; March 27; May 8).
Badister reflexus Lec. (Carabidae) (Feb. 6).
Blechrus nigrinus (Mann) (Carabidae) (Jan. 30).
Casnonia pennsylvanica L. (Carabidae) (Oct. 31; Nov. 14; Dec. 5, 26; Jan. 9; Feb. 6).
Clivina bipustulata Fab. (Carabidae) (Oct. 31; April 10).
Dicaelus furvus Dej. (Carabidae) (Aug. 8; May 29; June 12.)
Dicaelus purpuratus Bon. (Carabidae) (Aug. 8).
Evarthrus sigillatus (Say) (Carabidae) (July 4).
Harpalus erythropus Dej. (Carabidae) (July 25; Aug. 29).
Lebia atriventris Say (Carabidae) (Nov. 7).
Lebia grandis Hantz (Carabidae) (April 10).
Platynus basalis (Lec.)? (Carabidae) (Dec. 19).
Platynus 8-punctatus Fab. (Carabidae) (Oct. 17, 31; Jan. 23).
Tachys nubifer Csy.? (Carabidae) (Oct. 3).
Triliarthrus badiipennis (Hald.) (Carabidae) (Feb. 6).
Parandra brunnea Fab. (Cerambycidae—Long-horn beetle) (Dec. 5).
Cassida bivittata Say (Chrysomelidae—Leaf-beetle) (Oct. 31; Jan. 16).
Cerotoma trifurcata (Forst.) (Chrysomelidae) (Nov. 7; Jan. 30).
Chelymorpha argus Herbst (Chrysomelidae) (July 7; Jan. 9; March 27).
Lema trilineata Oliv. (Chrysomelidae) (Oct. 31; Jan. 9).
Metriona bicolor (Fab.) (Chrysomelidae) (Jan. 9, 23; Feb. 6, 13).
Oedionychis scalaris, Melsh. (Chrysomelidae) (March 6).
Oedionychis 6-maculata (Ill.) (Chrysomelidae) (Feb. 6, 27; March 27).
Phyllotreta sinuata Steph. (Chrysomelidae) (July 18; Oct. 3, 17, 31; Nov. 7, 28; Jan. 2, 9; Feb. 6).
Cincindela 6-guttata Fab. (Cincindelidae—Tiger Beetle) (June 12).
Hyperaspis undulata Say (Coccinellidae—Lady-bird) (Nov. 7).
Silvanus surinamensis L.? (Cucujidae—Grain beetle) (Nov. 14).
Conotrachelus erinaceus Lec (Curculionidae—Weevils) (Feb. 6; March 27).
Conotrachelus seniculus Lec. (Curculionidae) (Oct. 13).
Lixus terminalis Lec. (Curculionidae) (March 27).
Copelatus glyphicus Say (Dytiscidae—Predacious diving beetle) (July 18).
Agriotes insanus Cand. (Elateridae—Click-beetles) (March 27).
Asaphes memnonius Herbst (Elateridae) (July 25).
Drasterius sp? (Elateridae) (Oct. 31; Nov. 7; Jan. 9, 16).
Glyphonyx testaceus Melsh. (Elateridae) (Sept. 19; Jan. 9, 16; Feb. 27).
Melanotus communis Gyll. (Elateridae) (June 12).
Hister americanus Payk. (Histeridae) (May 1).
Hister vernus (Say) (Histeridae) (Oct. 31).
Lucidota atra (Fab.) (Lampyridae—Firefly) (June 19).
Glischrochilus fasciatus (Oliv.) (Monotomidae) (Feb. 6).
Carpophilus antiquus (Melsh.) (Nitidualidae) (Feb. 6).
Epurea rufa Rest. (Nitidulidae) (July 11; Aug. 22; Sept. 19; Oct. 3, 31; Nov. 14, 21; Jan. 2; Feb. 6; March 27; April 10).
Stelidota geminata (Say) Nitidulidae) (May 1, 8).
Stelidota 8-maculata Say (Nitidulidae). (July 4).
Pilopius piceus (Lec.) (Pselaphidae) (July 4, 11; Aug. 29; Sept. 12; Feb. 6; April 3).
Serica sericea (Ill.) (Scarabaeidae—Leaf-chafers) (March 27; April 17).
Xyloryctes satyrus (Fab.) (Scarabaeidae) (June 5).
Colon sp? (Silphidae—Carrion-beetle) (July 4).
Lathrobium collare Er.? (Staphylinidae—Rove-beetles) (April 3).

Lathrobium longiusculum Grav. (Staphylinidae) (Oct. 31; Dec. 5; April 10; May 1, 8).
Lathrobium simplex Lec.? (Staphylinidae) (July 4, 11).
Mycetoporus humidus (Say)? (Staphylinidae) (Feb. 6).
Olophrum obtectum Er. (Staphylinidae) (May 1; June 12).
Staphylinus viridianus Horn (Staphylinidae) (July 4).
Stilicus dentatus Say (Staphylinidae) (Nov. 7).
Tachyporus jocosus Say (Staphylinidae) (July 25; Aug. 1; March 27; June 19).
Tachinus pallipes Grav. (Staphylinidae).

Spiders

Cicurina arcuata Keys. (Agelenidae—Funnel-web spiders) (Dec. 26; Feb. 6, 27; March 27; June 19).
Hahnia agilis Keys. (Agelenidae—funnel-web spiders) (July 4, 25).
Hahnia cinerea Emer. (Aug. 22; Sept. 5; Oct. 17; Jan. 23; Feb. 6; April 10).
Castaneira bivittata, Keys. (Clubionidae) (Aug. 22; Sept. 19; Oct. 3; Feb. 13; April 3).
Phrurolithus alarius Hantz (Clubionidae) (Oct. 31; March 27; April 10; June 19).
Prosthesima rufula Banks (Drassidae) (Feb. 27; May 8).
Erigone sp? (Linyphiidae) (Nov. 7, 21; March 27).
Lephthyphantes sp? (Linyphiidae) (Nov. 14; April 24).
Microneta cornupalpis Camb. (Linyphiidae) (Dec. 5).
Lycosa lepida Keys. (Lycosidae—Wolf spiders) (Jan. 23; March 13).
Lycosa rubicunda Keys. (Lycosidae) (Feb. 27; March 27; April 10; May 1).
Pardosa sp? (Lycosidae) (July 11, 18; Aug. 1, 29; Oct. 3; Nov. 7; March 27).
Pirata sp? (Lycosidae) (Oct. 31; Jan. 9; Feb. 6).
Ceratinella sp? (Theridiidae—Comb-footed spider) (May 1).
Oxyptila conspurcata Thor. (Thomisidae—Crab-spider) (Oct. 31; Nov. 7; April 3, 24).

Myriapoda

Chilopoda (Centipedes).
Arenophilus bipuncticeps (Wood) (Oct. 31).
Bothropolys multidentatus (New.) (Aug. 8; Nov. 21; Jan. 16).
Linotaenia chionophila (Wood) (July 4, 11; Aug. 8; Nov. 21; Dec. 19; Feb. 6, 20).
Linotaenia fulva (Gager) (Aug. 8; Sept. 19; Oct. 17).
Notobius iowensis (Mein.) (July 4; Aug. 1, 8, 22; Sept. 19; Dec. 12; Feb. 6).
Otocryptops sexspinosus (Say). (July 4, 18; Aug. 22; Sept. 12, 19; Oct. 3; Dec. 5).
Poabius Vilabiatus (Wood) (July 11; Oct. 31; Nov. 28).
Diplopoda (Millipedes).
Cleidogona caesionnulata (Wood) (July 4, 11; Nov. 7).
Fontaria virginiensis (Drury) (Aug. 22).
Scytonotus granulatus (Say) (Aug. 22; Oct. 31; Nov. 7, 21, 28; Dec. 12).
Spirobolus marginatus (Say) (July 4, 18, 15; Aug. 29; Sept. 12, 19).
Striarea sp? (Oct. 31).

Mollusca

Pulmonate Snails.
Carychium exiguum (Say) (Auriculidae) (Oct. 31).
Agriolimax agrestis (Linn.) (Limacidae—Slug) (Nov. 7).
Phylomycus caroliniensis (Bosc.) (Phylomycidae—Slug) (Aug. 29; Oct. 31; Nov. 7, 14, 28).
Bifidaria pentodon (Say) (Pupidae) (July 11).
Succinea avara Say (Succineidae) (July 11; Oct. 3).
Zonitoides arborea (Say) (Zonitidae) (July 7; Aug. 8).
Zonitoides minuscula (Binn.) (Zonitidae) (July 4, 11; Jan. 2).

GROUND AND HERB STRATA

Diptera

Leptocera evanescens Tuck. (Borboridae) (Oct. 3; Nov. 7, 14, 28; Dec. 5, 12, 19; Feb. 6, 20).
Apiochaeta sublutea Mall. (Phoridae—Hump-backed fly) (Nov. 7; June 26).
Trichocera brumalis Fitch (Tipulidae—Crane-fly) (Oct. 31; Nov. 7; 21).

Hemiptera

Myodocha serripes Oliv. (Lygaeidae) (Oct. 31; Nov. 14, 28; Feb. 6, 27; March 27; April 3, 10; June 12).
Dicyphus gracilentus Parsh. (Miridae) (Type locality) (July 4; Aug. 8; Sept. 5, 19, 26; May 1; June 26).
Nabis ferus (L.) (Nabidae—Damsel bugs) (Oct. 17; Nov. 7, 28; Dec. 5, 12; Jan. 30).
Nabis roseipennis Reut. (Nabidae—Damsel bugs) (Oct. 31; Nov. 7, 14; Jan. 16; Feb. 6; March 13).
Podisus maculiventris (Say) (Pentatomidae—Soldier bug) (Oct. 17; Nov. 14; Jan. 9; Feb. 6; March 6).
Piesma cinera (Say) (Tingidae—Lace-bug) (Sept. 26; Oct. 3; Nov. 14).
Erythroneura obliqua var. parma McAtee (Cicadellidae) (Oct. 3; Dec. 5, 12; Jan. 2, 9, 23; Feb. 6).
Erythroneura vulnerata Fitch (Cicadellidae).
Scaphoideus scalaris V.D. (Cicadellidae).
Thamnotettix longulus G. & B. (Cicadellidae) (Sept. 19; Nov. 21).

Coleoptera

Notoxus monodon Fab. (Anthicidae) (Aug. 29; Sept. 12, 19, 26; Oct. 3, 10, 17, 31; Nov. 7, 21, 28; Dec. 5, 12, 19; Jan. 2; Feb. 6, 20, 27; March 27; April 3, 10, 17; May 1).
Tomarus pulchellus Lec. (Cryptophagidae) (Sept. 19; Nov. 7; Jan. 9; Feb. 20; April 3, 10).
Telephanus velox Hald. (Cucujidae) (Oct. 3, 31; Nov. 7, 14, 21, 28; Dec. 19; Jan. 9, 30; Feb. 6, 20).
Phytonomus nigrirostris Fab. (Curculionidae—Lesser clover-leaf weevil) (July 4, 11, 18; Aug. 22, 29; Sept. 12, 19, 26; Oct. 3, 31; Dec. 12, 19; Jan. 9, 23; Feb. 20, April 10, 17).
Hypera punctata Fab. (Curculionidae) (Aug. 29; Sept. 12; Oct. 31; Feb. 6).
Phontinus scintillans Say (Lampyridae—Fire-fly (June 26; July 4).

Spiders

Agelena naevia Walck. (Agelenidae—Grass spider) (Sept. 5, 12; Oct. 3; March 13; June 19).
Phidippus multiformis Emer. (Attidae—Jumping spider) (July 11, 25; May 1).

Mollusca

Circinaria concava (Say) (Circinariidae) (July 25; Aug. 8; Sept. 12, 19; Oct. 3, 17; Nov. 28; Jan. 9).
Vitrea indentata (Say) (Zonitidae) (July 11, 25; Aug. 29; Sept. 12, 19; Oct. 3, 17, 31; Nov. 7, 14, 28; Dec. 5; Jan. 23).

GROUND, HERB AND SHRUB STRATA

Diptera

Orthellia caesarion Meig. (Muscidae—Blue-bottle fly) (Nov. 7, 28; Jan. 6, 23).
Sciara sp? (Mycetophilidae—Fungus gnat) (Aug. 29; Sept. 19, 26; Oct. 10, 31; Nov. 7; April 3).

Hemiptera

Acanthocephala terminals (Dall) (Coreidae) (Aug. 8, 22, 29; Sept. 12, 26; Oct. 3, 10, 17, 24, 31; Feb. 6).

Lygus pratensis (L.) (Miridae—Tarnished plant-bug) (Oct. 3, 10, 31; Nov. 7, 28; Dec. 5, 12; Jan. 2, 16; Feb. 6, 13; March 13, 27).
Nabis sordidus Reut. (Nabidae—Damsel bug) (Aug. 8, 29; Sept. 5; Nov. 14).
Euschistus variolarius (P. B.) (Pentatomidae—Soldier bug) (Aug. 29; Nov. 7, 21, 28; Dec. 5, 12; Feb. 6; March 27; April 3, 10, 17, 24).
Hymenarcys aequalis (Say) (Pentatomidae) (Aug. 29; Oct. 31; Nov. 7; Dec. 12; Feb. 6; May 8).
Zelus exsanguis (Stål) (Reduviidae—Assassin-bug) (July 18, 25; Aug. 29; Sept. 26; Oct. 3, 10, 17, 31).
Corythucha aesculi O. & D. (Tingidae—Lace-bug) (July 4, 18; Sept. 12, 19; Oct. 17; Jan. 9; Feb. 13; April 3, 10, 24; May 1, 8; June 5, 12, 19).
Gargaphia tiliae (Walsh) (Tingidae) (Sept. 19, 26; Oct. 31; Nov. 7; Dec. 19).
Empoasca viridescens Walsh (Cicadellidae—Leaf-hoppers) (Sept. 19, 26; Oct. 3, 17, 31; Nov. 7, 14, 21, 28; Dec. 5, 19; Jan. 30; Feb. 6; Mar. 6).
Erythroneura comes var. basilaris (Say) (Cicadellidae).
Erythroneura comes var. maculata (Gill.) (Cicadellidae).
Erythroneura comes var. vitis Harr. (Cicadellidae) (Oct. 17; Nov. 28).
Erythroneura obliqua var. scutellaris (Gill.) (Cicadellidae).

Coleoptera

Lebia ornata Say (Carabidae—Ground beetles) (Dec. 9; Oct. 31; March 27; June 12).
Lebia scapularis Dej. (Carabidae) (Sept. 19, 26; Oct. 3; Jan. 3).
Chaetocnema confinis Crotch. (Chrysomelidae—Leaf-beetles) (Sept. 19, 26; Oct. 11; Nov. 14; May 8).
Diabrotica ittata Fab. (Chrysomelidae) (Aug. 29; Sept. 12, 26; Oct. 3, 10, 17, 31; April 10; May 1, 8; June 5).
Epitrix brevis Schw. (Chrysomelidae) (Sept. 19, 26; Oct. 3, 17; Jan. 6, 16, 23, 31; April 10; May 8; June 12, 19, 26).
Epitrix fuscula Crotch. (Chrysomelidae) (Sept. 19; Oct. 3, 31; Nov. 7, 14, 21; Dec. 12, 19; Jan. 9; Feb. 27; May 8).
Glyptina brunnea Horn (Chrysomelidae) (Sept. 26; Oct. 17; Feb. 6; June 5, 19).
Glyptina spuria Lec. (Chrysomelidae—Leaf-beetles) (Sept. 12, 26; Oct. 31; Nov. 7, 21; Dec. 5, 12; Jan. 9; Feb. 27; March 6, 13, 27; April 3, 10, 17; May 1, 8; June 12).
Xanthonia villosula (Melsh.) (Chrysomelidae) (July 3, June 19, 26).
Lathridiidae unidentified (Sept. 12; Oct. 3; Nov. 7, 14; Dec. 12; Feb. 6; March 27; April 3; May 1, 8; June 26).
Phalacrus politus Melsh. (Phalacridae) (Sept. 26; Oct. 3, 10, 17, 31; Nov. 7, 14, 21, 28; Dec. 5, 12, 19; Jan. 2, 9, 16, 23; Feb. 6; March 27; April 10, 17; May 1, 8; June 12).

Spiders

Philippus tripunctatus Emer. (Attidae—Jumping spider) (Sept. 26; Oct. 10, 17, 31; April 10).
Wala palmarum Hentz (Oct. 3, 31; Feb. 6; April 10; May 1).
Anyphaena rubra Emer. (Clubionidae) (July 19; Aug. 8, 29; Sept. 19, 26; Oct. 3, 10, 17, 31; Nov. 14, 21; Jan. 2, 16, 23, 30; Feb. 6, 20; March 6, 13, 27; April 10; May 1, 22).
Clubiona crassipalpus Keys. (Clubionidae) (May 15).
Dictyna muraria Emer. (Dictynidae) (Aug. 29; Sept. 5, 12, 19, 26; Oct. 3, 10, 17, 31; Nov. 21; Dec. 19; Jan. 2; Feb. 6; April 10; June 5).
Dictyna volupis Keys. (Dictynidae) (Feb. 20; March 6; May 15, 22, 29).
Sergiolus variegatus Hentz (Drassidae) (Oct. 10; Feb. 13, 27).
Epeira gibberosa Hentz (Epeiridae—Orb-weavers) (July 11, 18, 25; Aug. 8, 22, 29; Sept. 5, 12, 19; Nov. 7; Feb. 6; April 3; May 22; June 5, 12, 19, 26).
Tetragnatha laboriosa Hentz (Epeiridae) (July 11; Oct. 24; Nov. 7, 21, 28; Dec. 5, 19; Jan. 9; March 6, 13, 27; April 3, 24; May 1, 22).

Linyphia phrygiana Koch (Linyphiidae) (July 11, 18; Aug. 8, 29; Sept. 12, 19, 26; Oct. 10, 31; Nov. 7, 21, 28; Dec. 12; Jan. 9; Mar. 6; June 19).
Dolomedes idoneus Mont. (Pisauridae—Nursery-web weavers) (July 4, 11, 18, 25; Aug. 8, 29; Sept. 12, 19, 26; Oct. 17; Dec. 19; Feb. 6; March 27; April 10; June 12, 19).
Pisaura undata Hentz (Pisauridae) (July 11, 18; Aug. 1, 8, 22, 29; Sept. 12, 19, 26; Oct. 3, 17, 31; Dec. 19; Feb. 6; April 10; May 1; June 12, 19).
Philodromus ornatus Banks (Thomisidae—Crab-spiders) (Aug. 8, 29; Sept. 19; Oct. 3; June 26).
Xysticus elegans Keys (Thomisidae) (July 11, Aug. 1, 8, 15, 22, 29; Sept. 5, 12, 26; Oct. 10, 24; Nov. 7, 14, 21, 28; Dec. 5, 12, 19; Jan. 2, 9; Feb. 6, 20; March 27; April 10, 24; May 1, 15, 29; June 19, 26).
Vloborus americanus Walck. (Vloboridae) (Sept. 12, 19; Oct. 17).

Mollusca

Polygyra thryroides (Say) (Helicidae) (July 11, 18, 25; Aug. 8, 22, 29; Sept. 12, 19, 26).

HERB STRATUM

Diptera

Coenosia lata Walk. (Anthomyidae—Root-maggot flies) (May 1).
Macorcoenosia triseta Stein. (Anthomyidae) (May 8).
Phorbia fusciceps Zett. (Anthomyidae) (Nov. 28).
Borborus equinus Fall. (Borboridae) (June 12).
Camptocladius byosinus Schrank. (Chironomidae—Midges) (June 12).
Chironomus cristatus Fabr. (Chironomidae) (July 18).
Chironomus riparius Meig. (Chironomidae) (Sept. 26).
Chironomus sp? (undescribed) (Chironomidae) (July 3; Sept. 26).
Dexia vertebrata Say (Dexiidae) (July 18).
Dolichopus funditor Loew. (Dolichopodidae—Long-legged flies) (July 4).
Dolichopus longipennis Loew (Dolichopodidae) (June 12).
Dolichopus scapularis Loew (Dolichopodidae) (June 19, 26).
Chimomyza amoena Loew (Drosophilidae—Fruit flies) (June 12).
Drosophila melanica Sturt. (Drosophilidae) (Feb. 13).
Leucophenga varia Walk. (Drosophilidae) (Oct. 3).
Scaptomyza graminum Fall. (Drosophilidae) (Nov. 28; March 27).
Helomyza longipennis Loew (Helomyzidae) (June 12).
Heteromeringia sp? (Heteroneuridae) (June 26).
Chrysopilus modestus Loew (Leptidae—Snipe-fly) (June 26).
Boletina obscura Joh. (Mycetophilidae—Fungus gnat) (March 27).
Cordylura volucris Joh. (Mycetophilidae) (Nov. 21).
Exechia sp? (Mycetophilidae) (Nov. 21).
Mycetophila extincta Loew (Mycetophilidae) (June 12).
Neosciara sp? (Mycetophilidae) (June 5).
Batanobia pusilla Meig.? (Oscinidae) (Oct. 3).
Chloropisca glabra Meig. (Oscinidae) (Oct. 3; June 5).
Hippelastes flavipes Loew (Oscinidae) (Oct. 17; June 26).
Platypeza velutina Loew (Platypezidae—Flat-footed fly) (Oct. 3).
Sapromyza fraterna Loew (Sapromyzidae) (July 4, 18, 25; Aug. 8).
Sapromyza philadelphica Macq. (Sapromyzidae) (June 26).
Scatophaga furcata Say (Scatophagidae—Dung-flies) (April 24).
Scatophaga stercoraria L. (Scatophagidae) (Aug. 22).
Trypetoptera canadensis Macq. (Sciomyzidae) (June 12).
Sepsis violacea Meig. (Sepsidae) (Nov. 28).

Microphthalmia disjuncta Wied. (Tachinidae—Tachina-flies) (Aug. 22).
Sciasma nebulosa Coq. (Tachinidae) (Oct. 17).
Cladura flavoferruginea O.-S. (Tipulidae—Crane-flies) (Oct. 3, 17).
Dicranoptycha sobrina O.-S. (Tipulidae) (Aug. 22; June 19, 26).
Helobia hybrida Meig. (Tipulidae) (Oct. 17; Nov. 28).
Rhipidia domestica O.-S. (Tipulidae) (Oct. 24).
Tipula unimaculata (Loew) (Tipulidae) (Aug. 8).

Hemiptera
Triphleps insidiosus Say (Anthocoridae) (Oct. 3).
Geocoris uliginosus (Say) (Lygaeidae) (Sept. 26).
Macrolophus separatus (Uhl.) (Miridae) (July 11).
Acrosternum hilaris (Say) (Pentatomidae—Shield bug) (July 18).
Emesa brevipennis Say (Reduviidae—Assassin bug) (Aug. 8; Sept. 19).
Galgupha nitiduloides Wolff (Cydnidae—Burrower-bug) (July 11).
Balclutha punctata Thunb. (Cicadellidae—Leaf-hoppers) (Sept. 26).
Dikraneura carneola (Stål) (Cicadellidae). (Oct. 3).
Empoasca obtusa Walsh (Cicadellidae).
Stenocranus dorsalis (Thunb.) (Cicadellidae).
Acanalonia conica Say (Fulgoridae) (July 4, 11, 18).
Ormenis pruinosa Say (Fulgoridae) (July 11, 18; Aug. 29; Nov. 28).
Stobaera concinna Stål (Fulgoridae) (Dec. 19).

Hymenoptera
Chelonus sp? (Braconidae) (Sept. 26).
Cyanopterus sp? (Braconidae) (Aug. 15; Sept. 5).
Orgilus sp? (Braconidae) (Sept. 12).
Rhogas terminalis Cress. (Braconidae) (July 18).
Callimome sp? (Chalcidae) (Oct. 3).
Dibrachys boucheanus Ratz. (Chalcidae) (Oct. 17).
Tetrastichus sp? (Chalcidae) (Oct. 3).
Aenoplegimorpha sp? (Ichneumonidae) (Sept. 26).
Amblyteles mucronatus (Prov.) (Ichneumonidae) (Sept. 12).
Amblyteles w-album (Cress.) (Ichneumonidae) (Aug. 15).
Hoplismenus morulus (Say) (Ichneumonidae) (July 11).
Spilocryptus propodeum Cush. (Ichneumonidae) (Sept. 26).

Coleoptera
Calathus opaculus Lec. (Carabidae—Ground beetle) (Sept. 5).
Liopus fascicularis Harr. (Cerambycidae—Long-horn beetle) (Aug. 8).
Diabrotica 12-punctata (Fab.) (Chrysomelidae—Leaf-beetles) (Nov. 28).
Longitarsus melanurus Melsh (Chrysomelidae) (Sept. 26; Oct. 3; Nov. 28; April 10).
Oedionychis gibbitarsa Say (Chrysomelidae) (Oct. 10).
Rhabdopterus picipes (Oliv.) (Chrysomelidae) (July 4).
Chilocorus bivulnerus Muls. (Coccinellidae—Lady-beetles) (Oct. 3).
Megilla maculata DeGeer (Coccinellidae) (Nov. 21; June 19).
Acalles carinatus Lec. (Curculionidae—Weevils) (March 6).
Conotrachelus tuberosus Lec. (Curculionidae) (July 4).
Idiostethus subcalvus (Lec.) (Curculionidae) (May 8).
Idiostethus tubulatus (Say) (Curculionidae) (May 8).
Orchestes mixtus Blatch.? (Curculionidae) (June 26).
Byturus unicolor Say (Dermestidae) (June 19).
Limonius griseus Beauv.? (Elateridae—Click-beetles) (July 4).

Ludius attenuatus Say (Elateridae (July 4, 18).
Photinus pyralis L. (Lampyridae—Fire-flies) (July 4; June 19).
Pyractomena angulata (Say) (Lampyridae) (July 11; June 19).
Plateros canaliculus Say (Lycidae) (June 26; July 8).
Mordella triloba (Say) (Mordellidae) (July 4).
Brachypterus urticae Fab. (Nitidulidae) (Sept. 5, 12).
Brachytarsus sticticus Boh. (Platystomidae) (May 8).

Spiders
Maevia vittata Hentz (Attidae—Jumping spiders) (July 11; Aug. 29; May 29).
Plexippus puerperus Peck. (Attidae) (Sept. 19).
Anyphaena calcarata Emer. (Clubionidae) (May 8; June 26).
Argiope aurantia Lucas (Epeiridae—Orange garden spider) (July 1; Sept. 19).
Mimetus interfector Hentz (Mimetidae) (Sept. 19).
Theridion frondeum Hentz (Theridiidae) (Aug. 8).
Musumena asperata Hentz (Thomisidae—Crab-spiders) (Aug. 29; Sept. 12; June 19).
Misumena oblonga Keys. (Thomsidae) (June 12, 19).

Mollusca
Sphyradium edentulum (Drap.) (Endodontidae) (Oct. 17).
Vertigo milium (Gould) (Pupidae) (Oct. 3, 17).

HERB AND SHRUB STRATA

Diptera
Chironomus decorus Joh. (Chironomidae—Midge) (June 12, 19).
Pelastoneurus vagans Loew (Dolichopodidae—Long-footed flies) (Oct. 3; June 26).
Psilopus patibulatus Say (Dolichopodidae) (July 18; Aug. 22).
Psilopus scintillans Loew (Dolichopodidae) (July 25; Aug. 8, 22; Sept. 5).
Psilopus tener (Loew) (Dolichopodidae) (June 19, 26).
Sympychus lineatus Loew (Dolichopodidae) (Sept. 26; Oct. 3; May 1, 8; June 5, 12).
Batanobia coxendix (Fitch) (Oscinidae). (April 3).
Minettia lupulina Fab. (Sapromyzidae) (Aug. 8; June 19, 26).
Dicranoptycha winnemana Alex. (Tipulidae—Crane-flies) (July 18; June 15).
Tipula mingwe Alex. (Tipulidae) (June 5).
Tipula flavoumbrosa Alex. (Tipulidae) (June 5, 19).

Hemiptera
Paraxenetus guttulatus (Uhl.) (Miridae) (July 4, 11).
Jalysus spinosus (Say) (Neididae—Stilt-bug) (July 25; Aug. 8; Sept. 26; Jan. 9).
Deltocephalus inimicus Say (Cicadellidae—Leaf-hoppers) (Aug. 29; Sept. 12, 26).
Empoasca mali (LeB.) (Cicadellidae).
Empoasca rosae (L.) (Cicadellidae).
Gypona 8-lineata (Say) (Cicadellidae) (Aug. 25; June 16).
Scaphoideus auronitens Prov. (Cicadellidae) (July 4; Aug. 8).
Acanalonia bivittata Say (Fulgoridae) (July 4).
Ormenis septentrionalis Spin. (Fulgoridae) (July 4, 11, 18; Aug. 29; Nov. 28).

Hymenoptera
Microbracon sp? (Braconidae) (July 4; Sept. 26).
Ephialtes aequalis (Prov.) (Ichneumonidae) (Sept. 5, 12, 26).

Coleoptera
Podabrus rugulosus Lec. (Cantharidae) (June 5).

Chalepus nervosa Panz. (Chrysomelidae—Leaf-beetle) (July 4; Aug. 22, 29; Sept. 5, 12, 26).
Psyllobora 20-maculata (Say) (Coccinellidae—Lady-beetle) (May 8).
Apion sp? (Curculionidae—Weevils) (Sept. 26; Oct. 3, 10, 17; May 8; June 12, 26).
Gelus oculatus Say (Curculionidae) (Aug. 29; Oct. 17).
Mordellistena tosta Lec. (Mordellidae) (June 19, 26).

Spiders

Dendryphantes aestivalis Emer. (Attidae—Jumping Spiders) (Aug. 8, 22, 29; Sept. 5, 12, 19, 26; Oct. 10, 17; April 3; May 1, 22, 29).
Habrocestum pulex Hents (Attidae) (Aug. 29; Sept. 12, 19).
Zygoballus bettini Peck. (Attidae). (July 15; Aug. 22, 29; Sept. 5, 26; June 5).
Acrosoma rugosa Hentz (Epeiridae—Orb-weavers) (July 11; Aug. 8, 22, 29; Sept. 19; Oct. 10; June 19).
Acrosoma spinea Hentz (Epeiridae) (Aug. 15: June 19).
Epeira hortorum Hentz (Epeiridae). Aug. 29; Sept. 12, 19; Oct. 10, 17; Nov. 28; Feb. 20; May 1; June 12, 19).
Linyphia communis Hentz (Linyphiidae) (Sept. 12, 19; Oct. 17).
Tmarus caudatus Hentz (Thomisidae—Crab-spiders) (Oct. 31; March 27).
Hyptiotes cavatus Hentz (Uloboridae) (Sept. 12; Oct. 17; Jan. 9; Feb. 6; May 29; June 12).

LEAF AND SHRUB STRATA

Sceptonia nigra Meig. (Mycetophilidae—Fungus gnat). (Oct. 24, 31; Jan. 2).
Apanteles sp? (Braconidae—Parasitic Hymenopteron). (July 18; Sept. 26).
Caenocara bicolor Germ (Anobiidae—Beetle). (Oct. 17; Nov. 14).
Lina lapponica (L.) (Chrysomelidae—Leaf-beetle). (July 18; Oct. 17; Nov. 21; Dec. 5, 12; Jan. 16; June 26).

SHRUB STRATUM

Diptera

Xenocoenosia calopiga Loew (Anthomyidae—Root-maggot fly) (June 26).
Bibio fraternus Loew (Bibionidae) (May 8).
Forcipomyia specularis Coq. (Chironomidae—Midge) (Sept. 26).
Drosophila quinaria Loew (Drosophilidae—Fruit fly) (Oct. 31).
Allodia falcata Joh. (Mycetophilidae—Fungus gnats) (Nov. 28).
Sciara sciophila Loew (Mycetophilidae). (June 5).
Cetema procera Loew (Oscinidae). (June 12).
Calipe gracilipes (Loew) (Sapromyzidae) (June 26).
Alophora aeneoventris Will. (Tachinidae) (May 1).

Hemiptera

Euschistus tristigmus (Say) (Pentatomidae—Shield-bug) (Aug. 29).
Sinea spinipes (H.-S.) (Reduviidae—Assassin-bug) (Aug. 29).
Erythroneura tricincta var. catycula McAtee (Cicadellidae—Leaf-hoppers) (Sept. 26).
Graphocephala versuta (Say) (Cicadellidae) (Nov. 21).
Gypona pectoralis Spanbg. (Cicadellidae).
Phlepsius irroratus Say (Cicadellidae) (Aug. 29).
Scaphoideus immixtus Say (Cicadellidae).

Hymenoptera

Rhogas intermedius Cress (Braconidae) (Sept. 26).
Campoplex sp? (Ichneumonidae) (Oct. 3).
Epiurus sp? (Ichneumonidae) (Oct. 31).

Plectiscus sp? (Ichneumonidae) (Oct. 31).
Thymarus sp? (Ichneumonidae) (Sept. 19).

Coleoptera
Telephorus lineola Fab.? (Cantharidae) (July 4).
Scymnus fraternus Lec. (Coccinellidae—Lady-beetle) (May 1, 8).
Melanotus ignobilis (Melsh.) (Elateridae—Click-beetle) (June 26).
Ptilodactyla serricollis (Say) (Helodidae) (June 12).
Mordellistena trifasciata (Say) (Mordellidae) (June 19).
Pentaria trifasciata (Melsh.) (Mordellidae) (June 26).
Osmoderma scabra (Beav.) (Scarabeidae—Routh flower-beetle) (July 4).

Spiders
Wala mitrata Hentz (Attidae—Jumping Spiders) (Oct. 10, 31).
Epeira cornigera Hentz (Epeiridae—Orb-weavers) (Oct. 31).
Epeira domiciliorum Hentz (Epeiridae) (Aug. 22, 29; Sept. 12).
Epeira insularis Hentz (Epeiridae) (Sept. 12, 19; Oct. 10).
Epeira prompta Hentz (Epeiridae) (Oct. 10; Dec. 5; Jan. 30; March 13; June 19).
Epeira stricta Hentz (Epeiridae) (Sept. 26; Oct. 10, 17).
Bathyphantes micaria Emer. (Linyphiidae) (June 19).
Euriopis funebris Hentz (Theridiidae) (Oct. 10).
Steatoda borealis Hentz (Theridiidae) (Sept. 19).
Coriarachne versicolor Keys. (Thomisidae—Crab-spiders) (Sept. 19).
Ebo latithorax Keys. (Thomisidae) (Oct. 10).

It appears then that the animal sub-dominants in the elm-maple association are, during a considerable portion of the year, largely species which have migrated from or are in the course of migration to or from the forest edge or the adjacent meadows. The ecotone between forest and meadow has its own fauna as well as its own flora, of which the former is concerned not only with the forest border proper, but with a more extensive zone extending outward to the meadow and inward to the depths of the forest. In addition to the animals observed in this study, many larger forms have been observed to frequent and breed in the forest margin region. Shelford (1913) lists seven species of mammals and about thirty species of birds which breed in the forest or at the forest edge and feed in the open meadows or prairies. (See also Wood, (1910).)

The community of the forest edge is relatively permanent and relatively extensive, as permanent and as extensive as the savanna. But little forest or meadow within the savanna is far enough from the other chief association (or associes) of the region not to be dominated at some season of the year by those forms for the completion of whose life history both types of habitat are required. From the animal standpoint we then have the same subdominants occurring throughout the savanna, and some of the same societies occurring in both the grassland and forest associations, at different seasons of the year. From the animal standpoint the savanna is a unit community, dominated by forms, the adjustment of whose life cycles

to the climatic rhythm of the region is similar, identical or equivalent.

If the prairie region of the savanna is to be considered as an associes whose developmental processes are directed toward the deciduous forest climax, the forest communities bordering the prairies must also receive the designation of associes rather than associations. Whatever process of development affects one of these communities affects the other and the replacement of grassland by woodland in the forest border region would shift the range of migration of the species comprising the distinctive fauna of the savanna in the direction of the new dividing line between forest and prairie. A certain portion of woodland would thus lose its migrant population, with the consequent change in societies and subdominants, if not in dominants and become a part of the deciduous forest formation in its restricted sense.

The chief criterion, according to Clements, of the climax formation (plant) is the identity of vegetation-form of the dominants. Also "one or more of the dominant species must range throughout the formation as a dominant to a larger or smaller degree . . . The majority of the dominant genera extend throughout the formation . . . Most of the subdominants belong to the same genera. . . ."

No criterion closely comparable to vegetation-form can be applied to animal dominants. However, vegetation-form is a fundamental response to climate. The fundamental response to climate on the part of an animal is the character of its life cycle, the adjustment of the annual rhythm of the animal to the climatic rhythm of the habitat. We have seen that the adjustment of the life cycles of savanna animals to the climatic rhythm is definite and similar in so far as sub-dominants of the same seasonal societies are concerned. It is equivalent for subdominants belonging to different societies. The dominant animals, under primitive conditions, are now almost entirely absent. Their life cycles, however, were similarly adjusted to the climatic rhythm. Most of the subdominants are very widely distributed over the savanna region, and the dominants ranged similarly. It would seem, according to the above, that the animal community of the temperate savanna might be considered as an animal formation probably in the subclimax stage with the woodland and meadow associations as alternes. However, before a final terminology is adopted, it is necessary that more work be done in the correlation of the animal and plant communities of the region. Formations should not be delimited on the basis of vegetation-form alone, but the life histories of the dominant animals should be considered as well. The final solution of the problem requires the cooperative effort of plant and animal ecologists.

EXPERIMENTAL STUDIES

Reactions of Animals in Gradients

In spite of their many points of unsuitability for experimental work, spiders were chosen on account of their definite vertical distribution for experiments involving gradients in environmental conditions. Practically all of the web-building species show narrowly limited stratal relations. As examples the height above the ground of the web of the following species taken in the area considered may be cited:

Species	Average Height m	Maximum Height m	Minimum Height m
Acrosoma rugosa	1.25	2.25	0.3
Acrosoma spinea	0.7		
Linyphia phrygiana	1.5	3.0	0.3
Anyphaena	1.25	3.0	0.3
Uloborus americanus	0.7	2.0	0.3
Epeira gibberosa	0.7	2.0	0.3
Hyptiotes cavatus	1.0	1.5	0.3

These averages are based on a large number of collections, with the exception of *Acrosoma spinea*, which is included here only for comparison with *A. rugosa*. According to Shelford (1913) this species is usually found still lower.

Of the species mentioned above only a part were suitable, on account of abundance, size, etc., for prolonged experimentation. Faults for this purpose of some of the species sufficiently abundant were small size, pugnacity, sluggishness, tendency to build a maze of web in the experimental cage or to make a silken retreat in a corner of the cage no matter what the air conditions might be. One familiar with the behavior of spiders will readily supply additional difficulties.

The first series, undertaken with *Acrosoma rugosa* only, was an attempt to determine directly the relation of various factors to the height at which webs of the species are built. In a preliminary experiment ten spiders were placed in a small screen cage 45 cm high and left over night on a table in the laboratory. The next morning all had built webs, seven of them within two inches of the top, and the other three in the upper half. The cage was then reversed and one hour later all individuals had begun webs in the upper half of the cage.

In Experiment 7-19 (Table 1) ten individuals were placed under inverted battery jars 33 cm by 45 cm high on a laboratory table. Strips of corrugated paper were supplied for foot-hold, and the upper two-thirds of one jar was covered with black paper. Observations were then made every two minutes and the positions of the spiders recorded. The spiders consistently sought the upper part of each cage, regardless of the partial darkness in the one. Light does not seem to be a determining factor.

Forty-four spiders were placed in a 6-foot screen cage in the dark-room late in the afternoon. The next morning thirty were between 5 and 6 feet from the floor, nine between 2 and 3 feet from the bottom, and five on or near the bottom of the cage. The wooden crossbars at the bottom, at 3 feet, and at the top afforded good points for attachment of webs. This experiment indicates that the selection of the position for the web takes place almost, if not quite as well in darkness as in light, and is largely governed by architectural conditions.

TABLE I

Experiment No. 7-19. Showing the reactions of the spider *Acrosoma rugosa* Hentz, in a vertical light gradient.*

Minutes from	Control			Experiment		
3:40 P.M.	*1*	*2*	*3*	*1*	*2*	*3*
0	5	0	0	5	*0*	*0*
10	0	0	5	1		4†
20	0	2	3	1		4
30	0	1	4	0		5
60	0	1	4	0		5
120	0	1	4	0	0	5

* Five spiders were placed in each of two inverted glass battery jars 45×33 cm, one of which (experiment) was covered with black paper on the top and the upper two-thirds of the sides. The other was uncovered, and both stood on a laboratory table receiving light from a North window 3 M. distant. The spiders had been brought from the field the previous day. Temperature of the room was 80° F.

In the above record, the numbers in the columns 1, 2, and 3 represent, respectively, the number of spiders in the corresponding third of the cylinder (beginning from the bottom) after the time-interval designated in Column 1.

† On account of the covering, separate observations could not be made in the upper two-thirds of the cylinder except at the beginning and end of the experimental period.

TABLE 2

Summary of experiments on the reactions of spiders in gradients of the evaporating power of air.

Species	Exp. No.	Wet	Medium	Dry
Acrosoma rugosa	Evap.	0.0–0.8	0.2–1.4	2.2–2.8*
	1	59	43	138
	2	44	83	113
	3	74	45	121

	3a	56	44	140
	7	103	124	173
	7a	99	39	262
Totals		435	378	947†
Percent		24.7	21.5	53.8
Epeira gibberosa	Evap.	1.1–1.3	1.8–2.1	2.7–3.0*
	92	92	67	1
	92a	64	57	39
	92b	80	98	42
	92c	73	106	41
Totals		309	328	123†
Percent		40.7	43.1	16.2
Anyphaena	Evap.	1.8	2.8	3.7*
	12	23	15	28
	12a	71	14	2
Totals		94	29	30†
Percent		61.4	18.9	19.7
Dendryphantes aestivalis	Evap.	1.8	2.8	3.7
	11	48	19	53
	11a	38	19	63
	11b	35	17	68
Totals		121	55	184†
Percent		33.6	15.3	51.1

* Evaporation in cc. per hour.

† Totals of readings at one-minute intervals through the entire experiment.

TABLE 3

Summary of experiments on the reactions of spiders in gradients of air temperature.

Species	Exp. No.	1.	2.	3.
Acrosoma rugosa	Temp.	23.5°	26.0°	27.5°
	10	181	72	47*
	Percent	60.3	24.0	15.7
	Temp.	26.0°	27.0°	28.5°
	10a	179	94	27
	Percent	59.7	31.3	9.0
	Temp.	29.0°	33.0°	35.0°
	9	194	71	35
	Percent	64.6	23.7	11.7
	Temp.	33°	35°	36°
	9a	177	36	87
	Percent	59.0	12.0	29.0
Anyphaena	Temp.	20°	25°	29°
	103	119	44	77
	103a	134	1	105
	Total	253	45	182
	Percent	52.7	9.3	38

Dendryphantes aestivalis	Temp.	25°	30°	37°
	101	95	20	25
	Percent	79.2	16.7	4.1
	Temp.	25°	26°	28°
	101a	67	15	38
	Percent	55.8	12.5	31.7

* Totals of readings at one-minute intervals through entire experiment.

TABLE 4

Experiment 8. Showing the reactions of *Acrosoma rugosa* Hentz in a vertical gradient of the evaporating power of air.

	Experiment 8		
	Bottom Section	Middle Section	Top Section
Evap.	2.5cc	1.4cc	0.7cc
Minutes			
0	8	0	0
10	3	2	3
20	1	3	4
30	1	2	5
40	2	1	5
Total	87	83	150

(Readings at one-minute intervals)

Eight animals were placed in the lower third of the same cage used in previous experiments, set on end, and observations of their positions were recorded at one-minute intervals. The evaporating power of the air expressed in cubic centimeters of water evaporated from a standard atmometer in one hour is indicated at the head of each column.

Observations in the field showed that the most usual situation for a web of *A. rugosa* is a leafless shrub with lateral branches near enough to another point of attachment to make possible the characteristic structure of the web. If the dead shrub supplies a suitable point of departure the spider may swing to the other side and carry across the first line of the web, otherwise a thread is spun which is carried by an air current across the intervening space and becomes attached because of its viscous nature. Spiders often attempt to establish webs where there is no possibility of success by either method. Fruitless attempts several hours in duration may be made to establish a web from a seemingly suitable point of departure, and free lines several meters in length may be spun in the attempt to find a second point of attachment.

Additional experiments with this species included the observation of the reactions of the species in gradients of the evaporating power of air and temperature. Experiments 1, 2, 3, 3a, 7, and 7a illustrate the former, and Experiments 9, 9a, 10 and 10a are examples of the latter. Results of these experiments are recorded in Tables 2 and 3. In these experiments the cages and air conditioning apparatus described by Shelford and Deere

(1913) and Shelford (1914) and previously used by the author (1917, 1919) were utilized.

The tabulated results of these experiments show a strong tendency for the animals to seek the driest third of the cage, even when the evaporation amounts to as much as 2.8 cc per hour. This is an evaporating power much greater than that ordinarily encountered in the normal habitat. The maximum mean hourly evaporation observed for a one-week period was a little over 1 cc per hour, at the forest margin in the middle of July. Assuming, on the basis of observational data, that three-fourths of this evaporation took place in the day time, we obtain an hourly mean for daylight hours of about 1.5 cc. The spider concerned is never found in this area. Figured in the same way, the maximum hourly evaporation in the shrub stratum where this species is found could not have exceeded 1.25 cc. with the usual value much below this. The explanation of the experimental results is somewhat difficult. The only suggestion that offers itself is that the animal selects the place of highest evaporation available where other conditions are favorable. The evaporation at 1.25 m, thea verage height of the web of this species, is much greater than at ground level.

Summaries of experiments involving a gradient of air temperature are given in Table 3. Here the results indicate an optimum temperature of 23.5° or lower. As the lowest temperatures are found near the ground level, this factor would tend to regulate the height to which the spiders ascend but the natural vertical gradients of neither temperature nor evaporation are enough to determine the location of the webs. In fact, as shown in Table 4, which records the results of an experiment involving a vertical evaporation gradient with the low evaporation in the upper part of the cage, the spiders seek a higher level even if in so doing they pass into a region of lower evaporation. Whether a difference in evaporation would determine the height to which the animal would ascend, within the limits available in the field, was of course, a question impossible of solution with the small cages, etc., available.

The tendency to seek higher levels is, within certain limits, at least, in this species independent of the evaporating power and presumably of the temperature of air. While the animal reaches and builds its web at a level at which there is a certain balance between the optima selected in the laboratory, this height seems to be determined by mechanical and structural relations rather than by the direct effects of the conditions of the air.

Epeira gibberosa, which occurs at or near the top of the herb stratum at an average height of .7 m was also subjected to a gradient of the evaporating power of air. Experiments 92, a, b, and c, which are recorded in Table 2 show the reactions of this spider. In contrast with *Acrosoma rugosa* this species showed a preference for a region of less intense evaporation, aver-

aging about 1.8 cc per hour, a condition somewhat approximating the maximum evaporation at the level mentioned in the more open areas of the woods. Field experiments also showed that this species exhibits a strong positive phototropism. Other experiments were not successful because of the rather small size of the animal and the ease with which it is injured. The experiments just outlined give results which accord very closely with what one might expect from a knowledge of the habitat. The spider is found near the tops of the herbs, in the more open parts of the woods, often in full sunlight, in a region of a comparatively high evaporation.

Immature specimens of *Anyphaena* sp. found at an average height of 1.25 m, often in curled leaves or in similar sheltered places, protected by a silken tube, were also subjected to gradients in temperature and evaporating power of air. Summaries of experiments 12, 12a, 103 and 103a, Tables 2 and 3, illustrate the behavior of this species. The optimum temperature seems to be in the neighborhood of 20° C, and the most favorable evaporation at about 1.7 cc or less, per hour. The normal evaporation in a rolled leaf, and with the protection afforded by a silken tube, is, of course, much less than in an openly exposed web at the same height, where the maximum is probably somewhat greater than the value just given. The lowest temperature available was chosen as in the case of Acrosoma.

Dendryphantes aestivalis is a wandering spider inhabiting especially low shrubs and small trees. On account of the lack of a web or definite retreat it is less restricted in its normal daily movements than any of the forms previously discussed. In a gradient of the evaporating power of air, (Table 2), while there was a preference for the drier parts of the cage with an evaporating power of 3.7 cc per hour, this preference was not marked. The larger figures for the terminal portions of the cage may be explained by the tendency of the spiders to occupy the corners.

In a gradient of air temperature, as illustrated by Experiments 101 and 101a (Table 3) *D. aestivalis* also showed a preference for the lowest temperature available. This preference was very decided when a difference of 12° between the ends of the cage was maintained and less marked when this difference was only 3°.

Temperatures much below the outdoor summer temperature could not be maintained, with a flow of air, in the apparatus, but in each case the temperature chosen by the spiders used in the experiments was much below that prevalent in the open fields. It is probable that this temperature reaction is one of the important factors limiting the distribution, horizontally, and perhaps vertically of the species considered. Evaporation seems to be of lesser importance as the spiders show a preference for an evaporation much higher than that encountered in their natural habitats. The antagonistic action of the two stimuli may be partially responsible for the phenomena of vertical distribution of spiders, but it appears that

the physical environment afforded by plant structures is of considerably greater importance in this respect.

2. *Effect of Environmental Conditions on the Rate of Development.* In order to test the effect of temperature and humidity conditions on the time elapsing until emergence, cocoons of *Epeira gibberosa* Hentz, were gathered at various times during the autumn and winter, brought to the laboratory and kept under controlled conditions. Each cocoon was placed in a short piece of glass tubing of about 5 mm inside diameter and about 3.5 cm long, the ends of which were closed by a loose plug of cotton. The tubes were then fastened to strips of wood in groups of ten, for the sake of easier handling, and placed in the controlled experimental cages. A complete series involving contrasting humidities at all temperatures used, and vice versa, was not available, but an attempt was made to obtain widely variant conditions. Records of the conditions in the various cages were made with the aid of recording thermographs and hygrographs, and evaporation was, in most cases, determined by the use of the porous cup atmometer. The cages BH, BW, AL and ALL (See Table 7) were of glass and sheet metal over an earth-filled flowerpot, similar in every way, and the air was allowed to flow through all at the same rate. CLL was a small glass cage, while HI was an unlighted refrigeration chamber. Both were adequately ventilated, but the rate of flow of the air could not be compared with that in the other cages. All cages except HI were illuminated by daylight (passing through several thicknesses of glass) and AL and ALL were, in addition, during the day, illuminated by large nitrogen-filled daylight lamps. B was the large constant-temperature room in which cages BH, BW and CLL were located. Temperatures in this room were approximately constant, except for a noonday rise of from three to five degrees during the last six weeks of the experimental period. Cages AL and ALL were in an adjoining room, the temperature of which was variable, simulating a simplified ideal winter day. All figures given in this table represent the means of weekly data.

As the cages could not be opened without changing, for the time being, the conditions (especially the humidity) it was desired to maintain, the cocoons were examined but once a week, at the same time that it was necessary to open the cages to change the record sheets on the instruments. Although an error was introduced into the calculations in this way, it is felt that the disadvantages of this procedure were not as great as those attending a more frequent disturbance of conditions.

Control lots of cocoons were placed in glass tubes in the same manner and exposed to outdoor conditions in the screen-house adjoining the room in which the controlled apparatus was located. In some cases cocoons were changed from one experimental chamber to another. A considerable

number were from time to time transferred from less favorable conditions to the high temperature and high humidity of cage BH, or to BW, where the humidity was somewhat less.

It was assumed that the processes of development ending in emergence proceeded at a uniform rate under constant conditions, and that when a cocoon was transferred from one set of conditions to another the amount of development taking place in each was proportional to the product of the rate of development for that set of conditions by the time under those conditions. On this basis velocity factors were computed for each experimental cage. An example will suffice to illustrate the method. Comparing spider lots Aa and Ae (Table 5) we find that the first was left in cage HI for 69 days and then transferred to cage BH where 21 days elapsed before emergence. Lot Ae remained in cage BH an average time of 67 days before emergence. Assuming that both lots were at the same developmental stage at the beginning of the experiment, we may derive the following algebraic equation from the data just given:

$$69V_{HI}+21\ V_{BH}=67\ V_{BH},$$

where V_{HI} and V_{BH} represent the velocity factors for cages HI and BH, respectively, hence:

$$V=_{BI}1.5\ V_{BH}$$

Taking the velocity factor of HI as unity, we obtain the relative value of 1.5 for V_{BH}. Similarly, by comparing lots Ca and Cb, we obtain a value of 1.7. Further comparisons led to the adoption of 1.6 as an average value for V_{BH}, when compared to V_{HI} as 1.0. Similar calculations were made for the other sets of conditions, and the velocity factors given in Table 5 were obtained. The sums of the products of these factors by the number of days in the corresponding cages gave values approximately constant within each group of cocoons brought from the field on the same day. The further assumption was then made that all were in the same stage of development on October 15, and the number was obtained, which, when multiplied by the number of days elapsing between October 15 and the beginning of the experiment, and added to the number just mentioned, gave a number approaching a constant for the entire experiment. The figure thus obtained (0.65 for Epeira and 0.85 for Arachnophaga) represents the velocity factor for outdoor conditions. This does not represent, as do the other velocity factors, the relative velocity of development under a stable set of conditions, but is rather a summation of many velocity factors operating through the season. None of the velocity factors obtained in this manner should be considered as definite and exact quantities, but rather as a means by which certain relationships can be brought to the attention. The real velocity factor for a certain set of conditions would depend upon

the stage of development already reached by the organism and its previous physiological history. While the limitations of this method are rather obvious, it is perhaps almost equally evident that it is not limited in its application to the estimation of the comparative developmental value of experimentally controlled conditions. If we have definite knowledge as to the climatic conditions prevailing during a series of seasons, we may tentatively develop a velocity factor for each combination of conditions. Phenological predictions made on the basis of such calculations would undoubtedly be more likely of fulfilment than those made on the basis of temperature cumulations only, or than those based on any other single factor.

Table 5 summarizes the data obtained as to the time of emergence of the spiders under the different experimental conditions. It will be seen that the most rapid development took place in Chamber BH, with a mean temperature of 25.8° and with the air saturated with moisture. The rate in Chamber HI with a mean temperature of 18° and a mean relative humidity of 64 per cent was about six-tenths of this, provided the cocoons were removed to BH after a period of about fifty days. If retained longer at the lower temperature (and lower humidity) the true value of the factor would be much less, as is shown by the high value of the "constant" obtained in lots Df and Fd. These results indicate that development proceeded, up to a certain point, at the low temperature and low humidity of this cage, but that a limit was reached beyond which development was very slow, with the probability of the occurrence of death in a short time. In fact, as will be seen from Table 6, no spiders emerged unaided from cocoons kept in HI, and large numbers of well developed spiderlings were found dead in the cocoons in this cage. No spiders were able to emerge except in air of very high humidity.

Cage AL gave a velocity factor about two-thirds that of HI, with the difference that emergence was possible under the conditions prevailing here. The day temperature in AL reached an average of 21.2° while the night temperature fell, on an average, to 1.7° with a mean of 9.3°. The humidity averaged above 90 per cent. On account of the slowness of the processes of development here not all of the spiders had emerged when the experiment closed, but even at this low temperature complete development was possible. The threshold of development is evidently very low. No preliminary period of freezing was necessary for emergence, but the fact that the velocity factor for outdoor conditions seems to have nearly the same value throughout the winter suggests a stimulating effect of low temperature or of variable temperatures. Further data are necessary for the determination of the threshold of development and the point to which development may proceed at low temperatures without a high moisture content. The short time required for the emergence of the spiders from the

single productive cocoon of lot De is unexplained. This cocoon may have been formed several weeks earlier than the others.

The percentage of cocoons producing living spiders was about the same under the conditions prevailing in cages BH and AL, and in the lots placed first in HI and then removed to BH. The highest percentage of spider-producing cocoons was found in the control lot, Bh (Table 6). In this lot there were no dead spiders which could be identified as such when the cocoons were opened, and fifty per cent of the cocoons had either produced living spiders or still contained them at the end of the experiment.

A summary of the data from all experiments shows that the number of cocoons containing spiders, living or dead, totalled 48 per cent of the entire number, and of 52 cocoons examined on January 9, exactly half contained living spiders while the remainder were parasitized. Thus the mortality in unparasitized cocoons may be considered as zero in the control set.

None of the experimental conditions were as favorable for normal development as were outdoor conditions, although development took place more rapidly in several of the former. It will also be seen that the outdoor conditions were much more unfavorable for the development of the parasites. No spiders were able to emerge, in the experimental cages, where the relative humidity averaged less than 90 per cent, even under the most favorable temperature conditions, and at high humidity spiders were able to complete their development at a very low temperature. A variable temperature, or a period of medium temperature followed by high temperature with high humidity, seems to be more favorable than a prolonged high temperature, although the last mentioned condition produced the most rapid development. The first two conditions most closely approach those of the natural habitat.

It was evident that the hymenopterous insect parasitic on the eggs of this species (*Arachnophaga picea* Riley) was able to reach maturity and to emerge under much more varied conditions than those favorable for the development and emergence of the spiders. Records of the emergence of these insects were made in the same way as in the case of the spiders, and the same procedure was followed in obtaining velocity factors and in computing "constants." The data thus obtained are also given in Table 5.

The most rapid development took place in lot Ba, which was brought from the field on November 8 and placed in cage HI for two months, after which it was removed to cage BH. The value of the "constant" in this case is conspicuously low, and differs markedly from those computed from the data furnished by lots Aa, Cb and Dd, which were given the same treatment in the same sequence. The only difference between lots Aa and Ba was the length of time under outdoor conditions, as the latter was brought to the laboratory eight days after the former. Before October 31, the temperature had not fallen below the freezing point of water, but a

heavy frost, with a minimum temperature of $-3.3°$ occurred the morning of November 2. As the second lot developed so much more rapidly than the first, we must conclude that freezing was the cause of the variation. It appears, then, that the most rapid development of this insect takes place if it is subjected to freezing temperature for a short time, then to a moderate temperature for a considerable period, and finally, to a high temperature. The fact that development took place in about the same time in CLL (dry) and BH (wet) seems to indicate that, at high temperatures at least, humidity is not of great importance. The "constants" obtained from lots Cb and Dd were again of the more usual magnitude, indicating that further freezing did not increase the velocity of development. However, the stimulating effect of low temperature or of variation was such that throughout the series the velocity factor for outdoor exposure was nearly as large as that for cage HI with a much higher mean temperature. It is also evident that humidity was a more important factor at the lower temperatures.

Insects also developed more rapidly when subjected to a moderate temperature for a time after being brought from the field, than if introduced directly to a high temperature. This will be seen by comparing the data from lots Ba and Bb, Bc and Bd. Of these the second was introduced immediately into cage BH (high temperature, high humidity), the third was introduced first into CLL (low humidity) and then into BH, while the fourth was left in CLL. All developed much more slowly than the first, which remained for two months at the lower temperature before being subjected to the high temperature and high humidity. There seemed to be no difference between the CLL-BH combination and direct introduction into BH, while the cocoons left in CLL required an additional week.

The Time X Velocity Factor product was highest for Series A, E, and F. The higher value for the first group may be explained by assuming that without a preliminary freezing, the processes of development require a longer time. Series E and F gave high values because a longer time at low temperature did not further accelerate development.

The highest proportion of *Arachnophaga picea* developed from the cocoons of lot Da which were brought from the field on January 16 and immediately placed in the high temperature-moderate humidity chamber. Over 25 per cent of the cocoons of this lot yielded parasites, while the proportion among all cocoons in this chamber was nearly as great. This high proportion was also obtained from a CLL-BH combination, at the same temperature. HI alone and BH alone were very unfavorable. It was rather remarkable that no parasites were found in the control series subjected to outdoor conditions. The parasites in that lot evidently perished in the larval stage, as no exoskeletal remains were observed. Numbers of dead imagos were found in the HI series and none emerged unaided from cocoons retained in this environment throughout the ex-

perimental period. The combination of low humidity and medium temperature in this chamber seemed to allow development up to a certain point beyond which a change of some sort was necessary to avoid death. This could not have been due entirely to low temperature, as several insects emerged in each of the variable low temperature cages. In both of these, however, the moisture content of the air was greater than in HI. Moisture seems to be of little importance for the development of Arachnophaga at high temperatures, in fact saturated air seems to be less favorable for rapid development than air with a lower moisture content, but at low temperatures moisture becomes a limiting factor.

In only a few cases did both spiders and parasites develop in the same lot of cocoons. The lots concerned were Aa and Dd, Ab, and Bc. The two first mentioned were subjected to the HI-BH combination, medium temperature-low humidity followed by high temperature-high humidity, and in these the spiders completed their development in less time than the parasites. The remaining two were from cage AL, low temperature and high humidity. Here the parasites developed first, much sooner in the case of Bc which had been frozen before being brought to the laboratory. The parasites are able to complete their development in a dry environment, while the spiders can not emerge unless the humidity is above 90 per cent. While low and variable temperatures stimulate the development of both forms, this stimulus is more prominent in the case of the parasite, which also has a lower threshold of development.

TABLE 5

Length of time to emergence of spiders and parasites (*Arachnophaga picea*) from cocoons of *Epeira gibberosa* under various conditions.

Epeira gibberosa

Lot	Date Begun	Number of productive cocoons	Time in days in cages			Total number of days x velocity factor	Average
			1*	2	3		
Aa	Oct. 31	1	O 16	HI 69	BH 21	113.2	
Ab		2	O 16	AL 169		120.3	
Ae		2	O 16	BH 67		118.3	118.1
Be	Nov. 8	4	O 24	AL 165		122.9	
Bg		2	O 24	BH 56.5		106.6	117.5
Bi	Nov. 8	10	Control			126.8	126.8

* The number in this column indicates the number of days between October 15 and the date on which the experiment was begun.

Lot	Date Begun	Number of productive cocoons	Time in days in cages 1*	2	3	Total number of days x velocity factor.	Average
Ca	Jan. 9	2	O 86	BH 41		121.9	
Cb		5	O 86	HI 48	BH 14	126.4	
Cc		4	O 86	AL 90		114.4	121.2
Dd	Jan. 16	6	O 93	HI 41	BH 11.7	120.3	
De		1	O 93	BH 13		81.4	
Df		1	O 93	HI 92		152.5	119.4
Eb	Jan. 30	2	O 108	R† 10	BH 17	112.6	112.6
Fd	Feb. 6	1	O 114	HI 68		142.1	142.1
			Arachnophaga picea				
Aa	Oct. 31	2	O 16	HI 69	BH 56	131.7	
Ab		2	O 16	AL 146.5		120.0	
Ac		1	O 16	CLL 124		125.2	
Ad		1	O 16	ALL 169		131.8	126.7
Ba	Nov. 8	4	O 24	HI 61	BH 26.2	101.5	
Bb		1	O 24	BH 96		116.4	
Bc		2	O 24	CLL 61	BH 35	110.3	
Bd		3	O 24	CLL 103		113.1	
Be		2	O 24	AL 120.5		116.8	
Bf		1	O 24	ALL 138		117.0	110.2
Ca	Jan. 9	1	O 86	BH 34		107.1	
Cb		1	O 86	HI 48	BH 14	130.3	118.9
Da	Jan. 16	11	O 93	BW 39.7		118.8	
Db		2	O 93	B 34		110.1	
Dc		1	O 93	CLL 34		110.1	
Dd		1	O 93	HI 48	BH 14	136.2	118.2
Ea	Jan. 30	1	O 106	R 10	BW 24	122.6	122.6
Fa	Feb. 6	3	O 113	R 3	BH 21.7	120.3	
Fb		2	O 113	R 3	BW 24	122.6	
Fc		2	O 113	R 3	B 24	122.6	121.6

Velocity factors used in above table	AL	ALL	B	BH	BW	CLL	HI	O	R
Epeira	0.65			1.60			1.0	0.65	1.5
Arachnophaga	0.80	0.70	0.90	1.00	1.00	0.90	0.90	0.85	0.85

† The letter "R" indicates that the cocoons were kept in the laboratory for the number of days indicated in the next column.

TABLE 6

Viability of the spider *Epeira gibberosa* Hentz and its hymenopterous parasite *Arachnophaga picea* Riley under various conditions.

Lot	Cages		Dates	Trans.	End.	Numbers					Egg
	1	2	begin.			S	P	DS	DP	E	
Ae	BH		Oct. 31		Apr. 18	2	0	2		6	
Bb	BH		Nov. 8		Apr. 18	2	1	5		12	
Ca	BH		Jan. 9		Apr. 18	2	1	3		4	
De	BH		Jan. 16		Apr. 18	1	0	1		8	
Eb	R	BH	Jan. 30	Feb. 9	Apr. 18	4	1	0		5	
						11	3	11		35	
						16%	5%	16%		58%	
Aa	HI	BH	Oct. 31	Jan. 8	Apr. 18	1	2	4		3	
Ba	HI	BH	Nov. 8	Jan. 8	Apr. 18	0	4	2		4	
Cb	HI	BH	Jan. 9	Feb. 26	Apr. 18	5	1	6		8	
Dd	HI	BH	Jan. 16	Feb. 26	Apr. 18	6	1	0		3	
						12	8	12		18	
						24%	16%	24%		36%	
Af	HI		Oct. 31		Apr. 18	0	0	7	3	8	2
Bh	HI		Nov. 8		Apr. 18	0	1*	4	3	2	0
Cd	HI		Jan. 9		Apr. 18	0	0	4	1	5	0
Df	HI		Jan 16		Apr. 18	1*	0	8	0	1	0
Fd	R	HI	Feb. 6	Feb. 9	Apr. 18	1*	0	6	1	1	1
						2	1	29	8	17	3
						3%	1.5%	48%	13%	28%	4.5%
Da	BW		Jan. 16		Apr. 18	0	11	19	0	10	
Ea	R	BW	Jan. 30	Feb. 9	Apr. 18	0	1	5	0	4	
Fb	R	BW	Feb. 6	Feb. 9	Apr. 18	0	3	6	0	1	
						0	15	30	0	15	
						0%	25%	50%	0%	25%	
Ab	AL		Oct. 31		Apr. 18	2	1	11	0	6	0
Be	AL		Nov. 8		Apr. 18	4	3	1	1	1	0
Cc	AL		Jan. 9		Apr. 18	3	0	0	1	5	1
						9	4	12	2	12	1
						22%	10%	30%	5%	30%	2.5%

Lot	Cages 1	Cages 2	Dates begin.	Trans.	End.	Numbers S	P	DS	DP	E	Egg
Ad	ALL		Oct. 31		Apr. 18	0	1	4	1	4	0
Bf	ALL		Nov. 8		Apr. 7	0	1	3	2	3	1
						0	2	7	3	7	1
						0%	10%	35%	15%	35%	5%
Ac	CLL		Oct. 31		Apr. 18	0	1	6	0	3	0
Bd	CLL		Nov. 8		Apr. 18	0	5	7	0	7	1
Cd	CLL		Jan. 9		Apr. 18	0	0	10	0	10	0
Dc	CLL		Jan. 16		Apr. 18	0	1	5	0	4	0
						0	7	28	0	24	1
						0%	11 %	46%	0%	40%	1.6%
Bc	CLL	BH	Nov. 8	Jan. 8	Apr. 18	0	5	7	0	7	1
Db	B		Jan. 16		Apr. 18	0	2	0	0	2	
Fc	R	B	Feb. 6	Feb. 9	Apr. 18	0	0	8	1	2	
						0	2	8	1	4	
						0%	13%	53%	6%	26%	
Bi	Control		Nov. 8		Apr. 18	10	0	0	0	10	
						50%	0%	0%	0%	50%	

Explanation of table:

Column headings.

Numbers:—

Number of cocoons yielding living spiders. In this and the next column the (*) indicates living animals not yet emerged from the cocoon on April 18.

P:—Number of cocoons yielding living parasites.

DS:—Number of cocoons containing dead spiders on April 18.

DP:—Number of cocoons containing dead parasites on April 18.

E:—Number of cocoons empty or containing remains which could not be positively identified.

Egg:—Number of cocoons containing unhatched spider eggs.

TABLE 7

Conditions in experimental cages referred to in Tables 5 and 6.

Cage	Temperature (Degrees C)			Relative Humidity (Percent.)			Evap. Power of Air. (cc. per hour)
	Max.	Min.	Mean	Max.	Min.	Mean	Mean
BH	30.0	21.0	25.8	100%		100%	0.04
HI	19.5	16.5	18.0	69.5	56.7	63.9	0.52
BW	30.0	21.0	25.8	92.8	68.0	83.9	0.78
AL	21.2	1.7	9.3	98.2	86.8	93.6	
ALL	21.2	1.7	9.3	97.0	57.7	78.2	
CLL	30.0	21.0	25.8				1.00
B	30.0	21.0	25.8				1.00

SUMMARY OF BIOLOGICAL CONCLUSIONS

1. Random sampling of the upper soil, leaf, herb and shrub strata in the elm-maple forest showed variations of the animal population in general in inverse ratio to variations in the evaporating power of the air. This is the reverse from conditions in the pine dune community as found by Sanders and Shelford (1922).

2. A great and sudden increase in the insect population as determined by random sampling occurred in the early autumn, the maximum collections being made on October 3. This was due to the autumnal migration of hibernating species from the forest border and the adjacent meadows, which was associated with the gradual decline in temperature and an increase in the daily mean variability due to lower night temperatures. The inward migration occurred at the level of the normal summer habitat of the species concerned and was followed by a downward migration to the place of hibernation.

3. A similar increase, marking a migration in the opposite direction, was indicated by the character of the spring collections.

4. Of non-migratory animals especial attention was given to the spiders, which may be divided into three groups according to their manner of adjustment of life history to the annual rhythm of the deciduous forest. Most species pass the winter in hibernation in the adolescent state. The second group spends the winter in the egg case, hatching either in late autumn or early spring, while the third differs from the first only in a greater degree of activity during the winter.

5. The animal association of the elm-maple forest is characterized by the appearance of marked seasonal societies, those of spring and autumn being dominated, especially, by the migrant forms.

6. On the basis of interchange of societal subdominants between prairie and forest it is held that the savanna constitutes a unit animal community.

7. Experiments involving the reactions of spiders in gradients of the various environmental factors differing at the different levels in the forest indicate that these factors are probably of considerable importance in determining the horizontal and vertical distribution of the animals but that their relative importance is not the same for different species. Among web-building species the mechanical features of the environment as related to the support of the web are also of very great importance.

8. Cocoons of *Epeira gibberosa* Hentz, some of which were parasitized by *Arachnophaga picea* Riley were subjected to controlled atmospheric conditions, with results leading to the following conclusions:

a) High temperature (mean 25.8° C) and a relative humidity near the saturation point caused most rapid development of the spiders, but mortality was lowest under outdoor conditions.

b) Spiders were unable to complete development or to emerge except under conditions of high humidity.

c) The parasites developed most rapidly when allowed to remain in the open until after the occurrence of freezing temperatures, then placed for two months in a low temperature-low humidity chamber (means 18.0°C and 63.9 per cent), and finally removed to a high temperature (mean 25.8° C) high humidity chamber. The humidity at this temperature seemed to have the effect of increasing the mortality, however, while a lower humidity (mean 83.9 per cent) at the same temperature produced just as rapid development.

d) Mortality of the parasites was lowest when the cocoons were kept for the greater part of the time, at least, at a high temperature and a moderate or low humidity, and greatest under outdoor conditions.

e) The threshold of development of the parasite was found to be lower than that of the host. The host developed more rapidly, however, at high temperatures.

f) Relative velocity factors for each set of conditions were computed and the law that the summation of the products of the velocity factors by time gives a constant, was developed. This relation may be expressed as follows:

$$(T_1V_1+T_2V_2+\ldots\ldots\ldots+T_nV_n)=K$$

where T_1, T_2, etc. represent the length of time spent under each set of conditions, and V_1, V_2, etc., represent the corresponding velocity factors. When sufficient data are available such velocity factors may be computed for any set of conditions, and for any developmental process influenced by such conditions. Results thus obtained may be utilized in phenological predictions.

9. Data obtained as indicated above have a definite relation to the adjustment of the life cycles of the animals considered to the annual climatic rhythm of the temperate deciduous forest and savanna.

SUMMARY OF METEOROLOGICAL OBSERVATIONS

1. *Humidity*—Recording hygrographs, standardized each week, were used in obtaining humidity data. Two instruments were used, one (a hygrothermograph) in a shelter about 100 m from the western edge of the forest in McDougall's (1922) quadrat No. 76. The sensitive element of this instrument was about 60 cm above the surface of the ground. The other hygrograph was suspended about 10 m above the ground in a maple tree in quadrat No. 54.

The record sheets were ruled off into two-hour intervals, and this period was taken as the unit. The mean humidity for each period was estimated, the average of these means (Monday to Monday) being computed as the weekly mean humidity. The daily maxima and minima were also averaged and the daily drop in humidity below the preceding maximum and below the preceding base mean was computed. The latter term is defined as the mean relative humidity between the hours of 8 p.m. and 6 a.m. This period was chosen because it is a period of relatively uniform humidity and temperature, or at least the period of most uniform conditions.

The relative humidity curve shows a very low point during the third week (week ending July 18) and four high points, during the weeks ending September 5, November 28, March 13, and May 29 (Fig. 2).

Examination of the variation curves shows that, in general, a wide range accompanies a low mean relative humidity. This is because of the fact that the moisture content of the air rarely fails to reach saturation during the night hours, and a low mean relative humidity is almost always caused by a very low day-time value.

A comparison of the data from the station between the herb and shrub strata with those from the tree station shows an almost invariably greater mean relative humidity in the former situation and a greater mean daily range in the latter. There were three slight exceptions to the latter statement, and four cases in which there was no difference in the mean at the two stations. The average difference for the entire period of observation at both levels was 3.5 per cent.

Lorenz-Liburnau's data show the following differences of relative humidity between the ground level and a height of 11 m, in beech woods:

Time	Relative Humidity at 0 m. Minus Relative Humidity at 11 m.
Forenoon (6:17-11:00 a.m.)	5.8%
Mid-day (11:00-3:00 p.m.)	10.9
Afternoon (3:00-6:18 p.m.)	8.0

The greatest differences were observed between the ground and a height of 5 m. Data obtained by the use of atmometers, as will be shown later, would place the zone of the most rapid decrease in humidity within a meter of the surface of the ground. Lorenz-Liburnau obtained, as an average of 79 observations between May 23 and October 16, a difference of 7.73 per cent between the relative humidity at the soil surface and that at 11 m. His method, however, left entirely out of consideration the hours between 9 p.m. and 4:30 a.m.

The hygrograph records for the week ending September 12 were analyzed and the means for each two-hour period were obtained, with the following results:

Hours	Mean R. H. at 0.6 m.	Mean R. H. at 10 m.	Difference
6-8 a.m.	95.0%	95.0%	0.0%
8-10	90.0	84.3	5.7
10-12 m.	77.1	76.0	1.1
12-2 p.m.	77.0	71.3	5.7
2-4	80.5	70.3	10.2
4-6	86.0	73.7	12.3
6-8	88.5	81.8	6.7
8-10	92.8	87.5	5.3
10-12 n.	93.5	91.8	1.7
12-2 a.m.	93.7	92.0	1.7
2-4	94.0	93.0	1.0
4-6	94.8	95.3	— 0.5
		Average Difference	4.3

See Figure 6 for a graphic representation of the temperature and humidity variations during the "ideal day." The hygrothermograph records for the week are given in Figure 7. The low average difference, compared with that obtained by Lorenz-Liburnau, may be explained by the fact that his observations left out of consideration those hours when the humidity differs least at the various levels, and the fact that the lower level used in the present observations was not ground level but 60 cm above.

Relative humidity of the air is greatest at ground level in the forest and decreases upward, very rapidly at first and then more slowly. During early morning hours or during fogs, rains, etc.,there may be no gradient. The temperature relation is such that, even with the same amount of absolute humidity at the different levels, a gradient in this direction

would be present. However, the gradient, especially near the ground, is too abrupt to be caused by the slight temperature differences alone, and there is a gradient in absolute as well as relative humidity.

2. *Evaporating Power of Air.*—The use of the evaporating power of the air, determined by the porous cup atmometer, as a summation of the effects of temperature, humidity, air movement, insolation, etc., has been too well established by various investigators to require discussion here. During the season favorable for the use of the porous cup atmometer, i.e., during the season without temperatures below the freezing point of water, these instruments were exposed in twelve different places in and at the borders of the woods. Although observations at all of the stations were not begun on the same date, and although there were some interruptions due to accident, a fairly representative series of readings was obtained.

The atmometers were mostly new and had been standardized by the manufacturers. All were re-standardized after use, and in some cases more frequently. They were mounted in the customary manner, without rain correcting devices. Those in the trees were protected by a cylindrical guard of coarse wire netting.

Atmometers were exposed at the following stations:

1.—On the top of the instrument shelter 1 m above the surface of the ground, surrounded by large elm and maple trees and by lower trees and shrubs, such as ironwood, white ash, buck-eye, red oak, spice-bush, red-bud, etc.

2.—About 3 m from the instrument shelter, on the ground, under cover of a thicket of Benzoin. The porous cup was about 10 cm above the surface of the ground.

3.—At a height of 1.5 m on the south side of the trunk of an ash tree, 25 cm in diameter, about 1 m from the instrument shelter.

4.—At the same height, on the north side of the same tree trunk.

5.—At a height of 2.5 m, suspended under a leafy branch of a small hard maple, about 3 m from the instrument shelter.

6.—In a hollow stump about 20 m from the instrument shelter. The heart of the stump was decayed so that the cavity reached down to ground level. The cortex was also broken away on the southeast side leaving an opening about 20 cm in width.

7.—At the west edge of the woods in the short grass near the roadside. This atmometer was stolen during the week ending August 1, and observations at this station were discontinued.

8.—At a height of 6 m in an elm tree about 10 m from the instrument shelter.

9.—At a height of 10 m in a maple tree about 50 m from the instrument shelter in a group of large maple and elm trees.

10.—This instrument was first exposed at a height of 12 m at the top of

the same tree as No. 8. After September 13 it was removed to the top of a buck-eye midway between the instrument shelter and station 9.

11.—At the east edge of the woods, in tall grass. This station was selected after the interference with the atmometer at Station 7.

Table F gives the data obtained from this series of observations. Graphs in figure 2 illustrate the relations between the amounts of evaporation at the different stations.

Beginning at a rather high level during the first week of observation, evaporation reached a maximum during the week ending July 18. This was followed by a rapid fall and a minimum during the week ending September 5. From this point there was a gradual rise until October 24, when a second maximum occurred. The first maximum was due to high temperature and lack of rainfall, while the minimum following was due to a heavy rainfall, without, however, much diminution of temperature. The second maximum was due to a lack of rainfall and to greater air movement and insolation due to the falling of the leaves. The instrument at Station 1 was left until it was broken by freezing, during the week ending November 14. Atmometers were again replaced at four of the stations when danger of freezing was past in the spring. A high maximum was reached during the week of May 8, which was followed by a sharp decline due principally to the greater development of the foliage.

Although there are a few minor exceptions, the data show a constant gradient in the evaporating power of air, from the ground level upward. This is what would be expected in view of the gradient in humidity, temperature and light. Wind movement, also, probably increases upward, although no instrumental measurements of this factor were made.

It will be seen that, although the difference between the evaporation at Station 1 and half a meter higher on the trunk of the small tree (Station 3) was very small, there were only six weeks during the entire season when a difference was not recorded. The difference between the north and south sides of the trees was negligible except during the latter part of October, when the amount evaporated was about 0.9 cc per day less on the north side. This difference was evidently due to the greater exposure to sunlight of the instrument on the southern side. The differences between the 1 m level and the 1.5 m level were greatest during the weeks of August 1, August 15, and September 5. These were weeks of comparatively great rainfall, when the lower air strata were thoroughly saturated with moisture, due to the greater amount of water in the soil.

The evaporation from atmometer No. 5, suspended from a maple branch 1.5 m above No. 1, and 1 m above the instruments just discussed, followed that obtained from the latter very closely, falling below in two instances, the weeks of August 1 and April 24.

The evaporation from atmometer No. 9, at 10 m followed, in a general way, that at the stations previously discussed. It was, in almost every instance, greater than at the other stations, the exceptions being the weeks of September 26 and October 10. These exceptions were slight, and can be explained by the fact that the gradient became less marked at this time on account of the fall of the leaves, and that slight variations in any direction might be expected due to the later fall of leaves from some trees than from others.

The evaporation from atmometer No. 8, at 6 m above the surface of the ground fell between that from Nos. 5 and 9, except for the week of September 5, when it was higher than either. For the weeks of September 26 and October 3 it was practically the same as No. 9. The rise in the last three weeks is probably explainable by earlier fall of the leaves of the elm tree and the greater exposure to the west wind.

Atmometer No. 10, at the upper margin of the forest crown showed the greatest evaporation of all. The drop in the evaporation from this instrument and from No. 8 during the week of September 5 was partially due to the accumulation of air in the porous cups. The readings are given, however, as they were obtained.

Atmometer No. 2, near the ground varied almost exactly with No. 1, with an average difference of 3.2 cc per day.

The evaporation in the hollow stump (atmometer Number 6) followed that from atmometer No. 2 except, apparently, for the weeks ending July 11 and 18. This discrepancy was probably due to an error in filling the bottle on the former date. It was located in very poor light, and an error of that kind was very easy to make.

The evaporation from the forest edge stations is not illustrated in the figure. That at the west forest edge, in short grass, was very much higher than elsewhere, with the exception of the tree tops. At the east forest edge in long grass, the evaporation was about the same as at 6 m in the woods.

The comparative evaporation at the various stations was computed as the average daily rate between July 1 and October 10. In the case of Stations 1 to 6 inclusive, the calculations were made directly. In the case of the others, where observations did not cover the entire period, the result was obtained by comparing the evaporations recorded with those recorded at Station 1 for the same dates, and assuming that the relative ratios would hold for the entire season. The values thus obtained were as follows:

Station	1	2	3	4	5	6	7	8	9	10	11
Mean weekly evaporation cc.	9.16	5.96	9.90	9.63	10.4	4.14	14.03	12.30	12.31	15.71	11.91

Similar calculations were not made from the spring series of observations, but similar relations were indicated.

The gradient of the evaporating power of air in the forest is very striking, stations less than a meter apart, vertically, showing definite and constant differences. This is particularly true at the lower levels. At the higher levels the gradient still persists but is subject to irregularities due to the greater exposure and lack of uniform conditions. The steepest gradient, also, is near the ground. An organism passing from the air stratum just above the soil to the top of a tree would enter a region of three times the average evaporating power, and would encounter a still greater diurnal variation in evaporating power. Evaporating power is more than doubled in passing from the herb stratum to the upper shrub stratum. It is probable that conditions under fallen leaves and debris are somewhat approximated by those in the hollow stump. An animal traveling from the interior of such a hollow stump to its top would encounter double the evaporating power. Such considerations serve to point out the extreme importance of this environmental factor and to emphasize the steepness of the gradient in that region of the forest in which stratification of animals is most complete.

3. *Temperature.*—Temperature data were obtained mainly by the use of recording thermographs. During the greater part of the period of study three such instruments were in use, although minor accidents at times prevented the proper functioning of one or the other for short periods of time, and one failed almost entirely during the winter period of low temperature.

The sensitive element of the instrument recording soil temperatures was placed with its upper surface 10 cm below the surface of the soil, which was, in turn, covered by the usual carpet of leaves and other debris, making, perhaps, in all a layer 15 cm in thickness above the thermometer bulb. Of the air temperature instruments, the sensitive element of one was exposed on the north side of the instrument shelter previously mentioned, within which the mechanical parts of the two instruments were housed. The bulb of the instrument was protected from the direct rays of the sun and from falling water, but was exposed to the free circulation of the air.

The third instrument was of the self-contained type, and was suspended about 10 m above the surface of the ground with the hygrograph previously mentioned. The clock mechanism of this thermograph did not work well during the colder part of the year, and only partial readings were obtained after December 5. Figures obtained from this instrument after this date are not included in the tabulations or graphs.

A standard Weather Bureau type maximum and minimum thermometer set was also installed in the instrument shelter, with the bulbs exposed approximately as in the case of the recording instrument. This was used in checking the thermographs. The thermograph in the tree could, of

course, be checked with the mercury thermometers only when brought to the ground, which was done each week in order to change the record sheets.

The weekly record sheets were changed on Monday morning as in the case of the hygrographs. The data obtained from the thermograph records were treated in substantially the same way as those of the hygrographs, and the results are similarly tabulated and illustrated.

The summaries of the air temperature data at 60 cm and at 10 m are given in Tables C and D (Appendix), and the mean temperatures and mean variations at 60 cm are illustrated graphically in figure 1, C and E. The highest temperatures occurred during the first weeks of the period of observation, and there was a gradual decline until the week of January 30. Marked variations from the general downward trend were noted during the weeks of September 5, October 31, November 21, and January 9. The most rapid declines in temperature were between October 31 and November 14 and between January 9 and January 23. After January 30 the trend was again upward, with reversals occurring during the weeks of February 20, March 6, April 24, and May 22. The variation, from week to week, of the mean range was almost as great as that of the mean temperature. The excessive temperatures of the first weeks were accompanied by high variability but thereafter, until the end of October, and during the spring, the higher temperatures were accompanied by a smaller range. During the winter, however, high temperatures were associated with a great mean daily range. In other words, the high means of mid-summer were occasioned by a lack of the usual low nightly minimum. The chief factor in producing a low mean in the winter was the absence of a high mid-day rise. The relation existing between the maxima and the "base means" is accordingly of importance.

With a few exceptions the weekly mean temperatures at 10 m were higher than those recorded near the ground. Exceptions to this rule were recorded for the entire month of October and a portion of November. Observations at the German forest meteorological stations showed, for deciduous forests, a reversal of the ordinary forest temperature gradient coinciding with the fall of the leaves. Thus, during the leafless season, the forest agreed with the open country in exhibiting a decrease of temperature upward. If the observations at the higher level had been continued throughout the winter it is probable that this reversal would have become more evident. The mean difference in temperature at the two stations during the period of complete records at both levels was 0.36° C., which would correspond to a difference of 1.94° F. per hundred feet, or approximately the figures (2° F) obtained by the German investigators, according to Harrington (1893).

The data of Lorenz-Liburnau (1890) show an average difference of temperature between ground level and 11 m in beech woods, according to numerous scattered observations, as follows:

Time	Temperature at 0.0 m. Minus Temperature at 11 m.
Early morning (2:55-5:25 a.m.)	−0.1°C
Forenoon (6:15-11:00 a.m.)	0.35°
Mid-day (11:00 a.m.-3:00 p.m.)	1.07°
Late afternoon (3:00-6:40 p.m.)	1.09°
Evening (5:50-9:55 p.m.)	0.44°

These observations covered the period between May 23 and October 28, near Vienna. While it was not practicable to calculate the differences for the various hours of the day throughout the period of observations, this was done for a week of average days without disturbing influences. The hygrothermograph records for this week (ending Sept. 12) are reproduced as Fig. 7. A compilation of the numerical data for each two-hour period of the day gives the following results:

Week Ending Sept. 12, 1921—See Figure 6

Time	Mean Temp. at 10.0 m.	Mean Temp. at 0.6 m.	Difference
6-8 a.m.	16.28°C	16.11°C	0.17°C
8-10	19.39	18.17	1.22
10-12 m.	22.06	20.78	1.28
12-2 p.m.	23.33	22.00	1.33
2-4	23.11	22.17	0.94
4-6	21.89	21.67	0.22
6-8	20.61	20.00	0.61
8-10	18.72	19.11	−0.39
10-12 n.	18.11	17.94	0.17
12-2 a.m.	17.17	17.44	−0.27
2-4	16.44	16.61	−0.17
4-6	15.39	16.33	−0.94
		Average Difference	0.34°C

The average difference for this week is of the same order of magnitude as the average for the period of complete records as previously given. The variations in the vertical temperature gradient during the nycthemeral cycle also seem analogous to its variations during the annual cycle, in that a reversal takes place during the cooler periods in each case.

As the temperature at the higher station was greater during the warmer hours, and lower during the early morning, it follows that the mean variability of temperature was greater at this level. This was true during the summer and early autumn months. During the winter the mean variability was greater at the lower level, due, probably, to the greater effect

of the sun on the temperature near the ground after the disappearance of the protective leaf-canopy.

Soil temperature was much more uniform than air temperature, and that within the forest, according to numerous observers, is much more uniform than that in the open at an equal depth. This is due, largely, to the lack of insolation and to the protective blanket of leaves and other ground litter. During the months when the deciduous trees were in leaf the maxima came at about 4 p.m. and the minima about 8 a.m., although sometimes delayed until 10 a.m. The variations became greater as the leaves fell, then decreased again as the ground froze, remaining very slight throughout the winter. A sudden rise, accompanied by daily variations of as much as 4° C. occurred during the week of March 13. This represented the temperature changes accompanying the thawing of the soil moisture during a series of early spring rains. Until the middle of May variability of soil temperature remained high.

Soil temperature data are given in Table E (Appendix) and illustrated in Figure 2. Although the mean soil temperature showed variations in the main closely correlated with those of the air near the surface of the soil, this mean, during the summer was about 5° below the air mean. Beginning with the week of November 14, a lag became apparent and the magnitude of the changes from week to week became decidedly less in the soil. During this period the mean temperature of the soil averaged higher than that of the air, thus reversing the condition found in the warmer season. The spring reversal occurred during the week of March 13, a period of heavy rain.

In summer the temperature increases from the soil upward to the forest crown; in winter the highest mean temperatures are in the soil and temperature decreases upward. In summer the temperature is most variable in the forest crown and least so in the soil; in winter the soil is still the most stable, but the greatest variation is found in the air stratum just above the soil.

4. *Light*—It was not possible, on account of lack of time and the unsuitability of apparatus for continuous observation, to conduct extensive observations on the quality and quantity of light available for organisms at various levels of the woods, and at various times. However, a short series of readings was made with the Macbeth Illuminometer. For details see Table G, Appendix. These readings were taken in the period between noon of August 29 and noon of August 30, while supplementary readings were taken on July 30 and August 22. Both of the days last mentioned, however, were unfavorable for comparative observations on account of partial cloudiness. On August 29 and on the day following, until about noon, the sky was clear, although somewhat hazy, and clouds did not begin to interfere with the readings until after noon.

Observations were taken at the ground level, under the shelter of a leaf mosaic and at the height of 1.25 m in a group of tall maples with fairly dense foliage, and in a sunny glade at the western edge of the woods. The test plate was horizontal in position in every case, and an amber filter was used to equalize the color values of the standard lamp and daylight.

Additional readings were taken at each station with the use of color screens, but as it has been impossible to obtain a spectrophotometric analysis of these screens in comparison with a similar analysis of the light emitted by the standard lamp, the data thus obtained are omitted here. The results indicated, however, a variation through the day in the relative constitution of the light as well as a difference in the quality of the light at different levels in the forest and in the open glade. As observations could not be taken at any two places at exactly the same time, any evidence based upon small differences must remain inconclusive.

As to intensity of light the results were much more definite. The light at 1.25 m in the shrub stratum but once during the day reached one per cent of the intensity of full noon sunlight. The maximum reading at this level, at noon, being 1170 meter-candles, while that in an open glade in the forest at the same height, in full sunlight, was 96650 meter-candles. At the ground level, under cover of herbage the highest reading was about 0.35 per cent of full sunlight, or 378 meter-candles. Both of the forest readings were taken in the shade. Throughout the day, flecks and small patches of sunlight find their way through the leafy canopy. Their intensity is difficult to measure, but the smaller flecks probably approximate one-half of full sunlight intensity, and larger areas have their intensity but little diminished. The difference between light at the lower levels in the forest and that at corresponding levels outside is very large, and the ratio of light intensity between the ground stratum and the shrub stratum may be as high as one to three or four. This factor has been little considered in connection with the study of the distribution of animals, but it deserves thorough consideration now that instruments for its measurement are being developed.

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PLATE I

EXPLANATION OF PLATE I

Animal Population Data.

Total population, and population of the shrub, herb, leaf, and ground strata of an area of four square feet in the forest.

A—Total population.
B—Population of the herb stratum.
C—Population of the shrub stratum.
D—Population of the leaf stratum.
E—Population of the soil stratum.

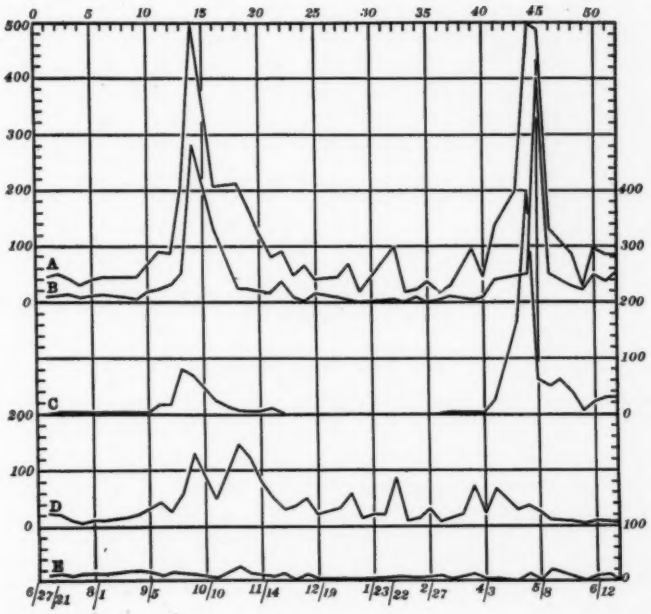

PLATE I

ANIMAL ECOLOGY OF AN ILLINOIS ELM-MAPLE FOREST

WEESE

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PLATE II

EXPLANATION OF PLATE II

Temperature, Humidity and Evaporation Data.

Time is represented horizontally, each smaller division corresponding to one week, beginning with the week ending July 4, 1921.

A—Mean relative humidity at Station A, 0.6 M. above ground surface.
B—Mean daily variation in relative humidity at Station A.
C—Mean Temperature at Station A, 0.6 M. above ground surface.
D—Mean soil temperature, Station A, 0.1 M. below ground surface.
E—Mean daily variation in air temperature, Station A.
F—Mean daily variation in soil temperature, Station A.
G—Average daily evaporation from a standard porous cup atmometer at Station 3 (See page 57).
H—Average daily evaporation at Station 1.
I—Average daily evaporation at Station 2.
J—Average daily evaporation at Station 9.
K—Average daily evaporation at Station 5.
L—Average daily evaporation at Station 6.
M—Mean daily evaporation for the entire season from each station.

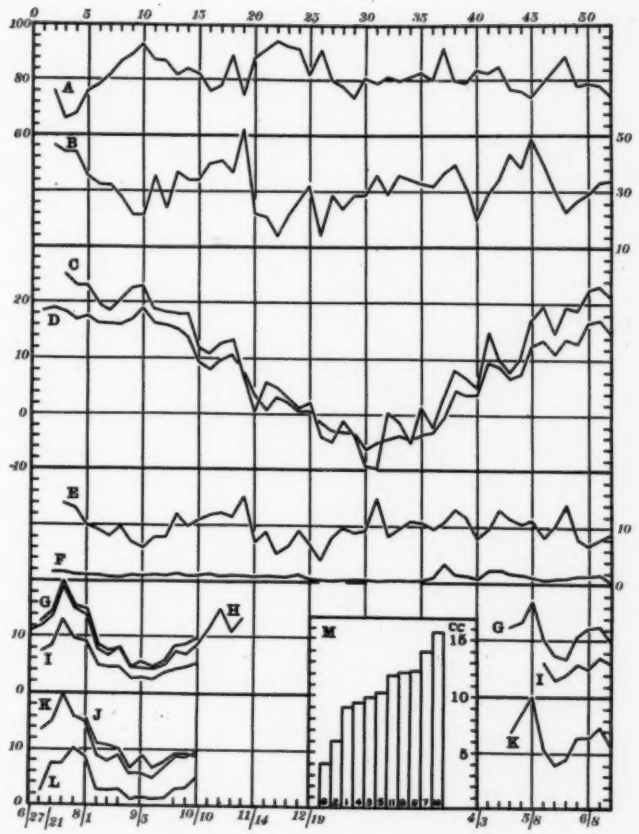

PLATE II

ANIMAL ECOLOGY OF AN ILLINOIS ELM-MAPLE FOREST

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PLATE III

EXPLANATION OF PLATE III

Seasonal Occurrence of Insects (Coleoptera).

Time is represented as in Figure 1. The vertical scale is relative, only, and is not the same for all species.

The solid line represents the relative numbers found in the leaf-soil strata, the broken line the herb stratum, and the dotted line the shrub stratum.

A—Diabrotica vittata Herbst.
B—Notoxus monodon Fab.
C—Phalacrus politus Melsh.
D—Phytonomus nigrirostris Fab.
E—Telephanus velox Hald.
F—Glyptina spuria Lec.
G—Epitrix brevis Schw.
H—Epitrix fuscula Crot.
I—Chaetocnema confinis Crot.
J—Phyllotreta sinuata Steph.

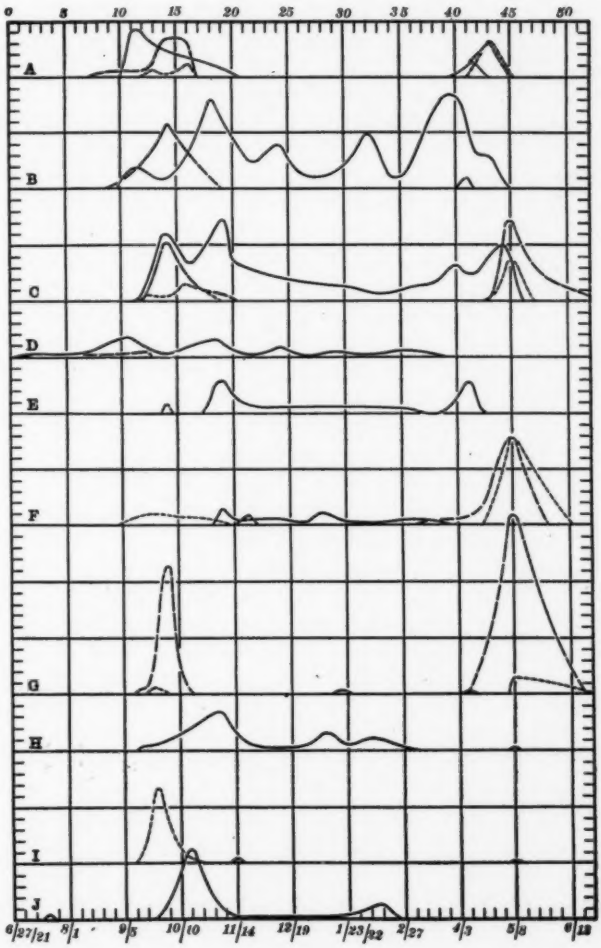

PLATE III

ANIMAL ECOLOGY OF AN ILLINOIS ELM-MAPLE FOREST

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PLATE IV

EXPLANATION OF PLATE IV

Seasonal Occurrence of Insects (Coleoptera and Hemiptera) and Spiders.

In Graph K the different strata are indicated as in Figure 4. In Graphs P, Q and T, the heavy lines represent adult spiders and the light lines young spiders. In Graphs L, M, N, O, R, and S the total population only is shown.

K—Longitarsus melanurus Melsh.
L—Corythucha aesculi O & D.
M—Corimelaena pulicaria (Germ.).
N—Lygus pratensis (L.).
O—Blissus leucopteris (Say).
P—Dendryphantes aestivalis Emer.
Q—Uloborus americanus Walck.
R—Anyphaena rubra Emer.
S—Dictyna sp?
T—Xysticus elegans Keys.

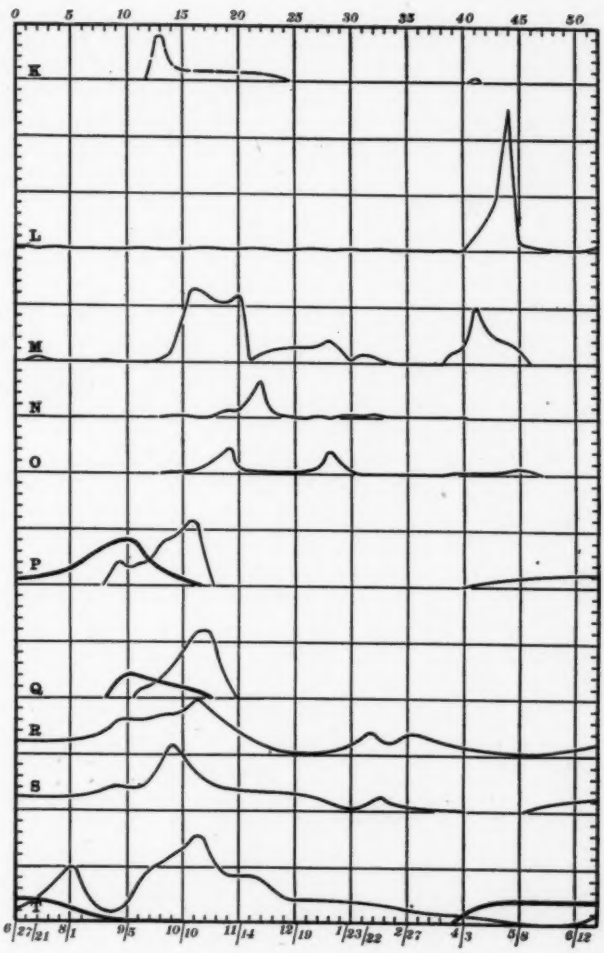

PLATE IV

ANIMAL ECOLOGY OF AN ILLINOIS ELM-MAPLE FOREST

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PLATE V

EXPLANATION OF PLATE V

Seasonal Occurrence of Spiders and Insects (Cicadellidae).

For explanation see Figures 4 and 5.

U—Linyphia phrygiana Koch.
V—Acrosoma rugosa Hentz.
W—Epeira gibberosa Hentz.
X—Tetragnatha sp?
Y—Empoasca viridescens Walsh.
Z—Total Cicadellidae and Erythroneura obliqua Say.

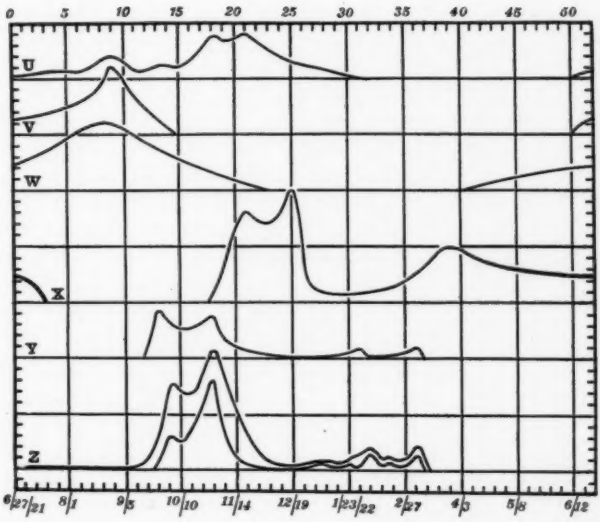

PLATE V

ANIMAL ECOLOGY OF AN ILLINOIS ELM-MAPLE FOREST

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PLATE VI

EXPLANATION OF PLATE VI

Temperature and Humidity Data.

Mean temperature and mean relative humidity of an ideal day (computed from the two-hour means for the week ending September 13, 1921) at the 0.6 m. and 10 m. levels in the forest.

A—Humidity.

B—Temperature.

The upper curve of A and the lower curve of B represent conditions at the 0.6 m. level.

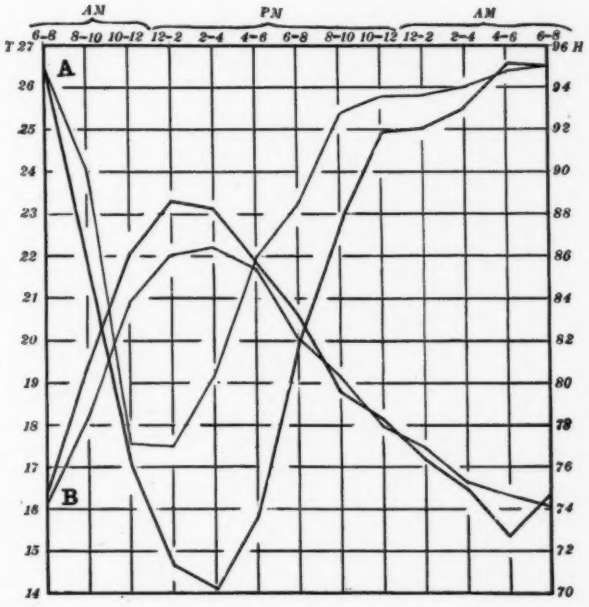

PLATE VI

ANIMAL ECOLOGY OF AN ILLINOIS ELM-MAPLE FOREST

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PLATE VII

EXPLANATION OF PLATE VII

Temperature and Humidity Data

Hygrothermograph records for the week ending September 12, 1921, at the 0.6 m. and 10 m. levels.

The lower curve in each chart is the temperature record. The temperature range of the chart is indicated. 100% humidity is at 38° and 50% humidity at 10° on the chart.

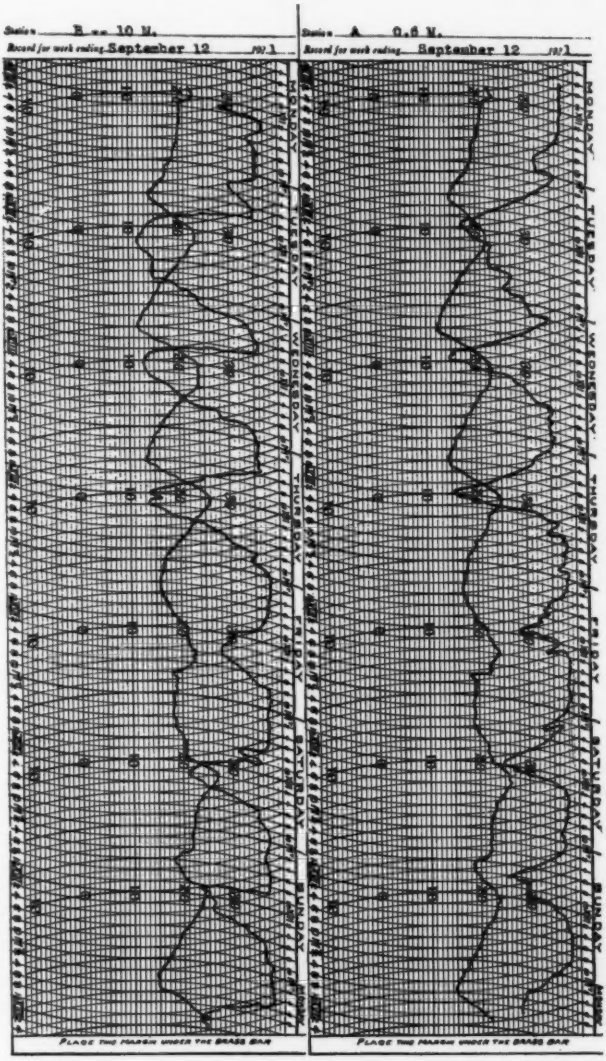

PLATE VII

ANIMAL ECOLOGY OF AN ILLINOIS ELM-MAPLE FOREST

WEESE

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TABLE A

Relative Humidity Data Station A, 0.6 m. above ground surface.

Week ending	Week No.	Abs. Max.	Abs. Min.	Mean Max.	Mean Min.	Mean R. H.	Base Mean	Total Range	Mean Range	Mean Range Below Base
July 11	2	100	40	93.7	48.0	74.7	87.1	60	45.7	39.1
July 18	3	94	35	84.1	40.4	66.1	76.5	59	43.7	36.1
July 25	4	95	35	86.1	41.7	68.6	79.4	60	44.4	37.7
Aug. 1	5	94	42	88.1	53.5	75.8	83.3	52	34.6	29.8
Aug. 8	6	95	42	90.0	58.5	77.6	85.2	53	31.5	25.7
Aug. 15	7	96	42	94.4	62.8	82.4	91.2	55	31.6	28.4
Aug. 29	8	100	64	98.1	70.5	86.8	92.2	36	27.6	21.7
Sept. 5	9	100	59	99.9	78.3	89.2	96.5	31	21.6	18.2
Sept. 12	10	100	61	99.8	78.0	93.2	97.7	39	21.8	19.7
Sept. 19	11	100	52	97.5	62.5	87.5	91.2	48	35.0	28.7
Sept. 26	12	99	58	95.7	71.5	87.2	91.2	41	24.2	19.7
Sept. 26	13	100	47	95.1	58.0	82.3	90.2	53	37.1	32.3
Oct. 3	14	100	43	96.0	62.1	84.1	91.9	57	33.9	28.9
Oct. 10	15	100	55	95.9	63.3	81.8	90.0	45	33.6	27.6
Oct. 17	16	100	46	96.0	56.0	76.1	90.8	54	40.0	34.8
Oct. 24	17	100	49	95.5	54.4	77.9	87.8	51	41.1	33.4
Oct. 31	18	100	41	100.0	63.0	88.6	96.4	59	37.0	34.4
Nov. 7	19	100	39	96.0	44.4	75.5	91.3	61	51.6	46.9
Nov. 14	20	100	59	95.5	73.3	88.1	92.5	41	22.2	19.2
Nov. 21	21	100	52	98.1	77.0	91.3	95.3	48	21.1	18.3
Nov. 28	22	100	60	99.3	85.3	94.5	97.6	40	14.0	12.3
Dec. 5	23	100	68	98.7	77.7	92.1	97.4	32	21.7	20.4
Dec. 12	24	100	63	99.4	72.7	90.8	96.4	37	26.7	23.7
Dec. 19	25	100	50	93.0	60.3	82.5	87.7	50	32.7	27.4
Dec. 26	26	100	57	95.3	81.9	91.4	93.5	43	13.5	11.7
Jan. 2	27	95	38	86.3	57.7	79.3	82.0	57	28.6	24.3
Jan. 9	28	100	47	86.0	60.5	78.5	53.0	25	23.3	23.3
Jan. 16	29	100	48	87.4	58.8	74.0	81.3	52	28.6	22.5
Jan. 23	30	100	50	91.7	63.1	81.2	88.4	50	28.6	25.3
Jan. 30	31	98	51	91.8	56.7	79.3	85.7	47	35.1	29.0
Feb. 6	32	100	43	92.4	63.3	81.3	86.7	57	29.1	23.4
Feb. 13	33	100	48	92.3	55.8	80.3	86.2	52	36.5	30.4
Feb. 20	34	98	44					54		
Feb. 27	35	100	42	97.0	64.0	82.9	91.8	58	33.0	27.8
Mar. 6	36	100	58	95.0	63.1	80.0	88.7	42	31.9	25.6
Mar. 13	37	100	47	97.0	60.0	91.6	93.6	53	37.0	23.6
Mar. 20	38	100	31	94.0	54.9	80.2	89.8	69	39.1	34.9
Mar. 27	39	100	46	94.9	63.9	79.2	89.0	54	31.0	25.1
Apr. 3	40	96	47	92.1	72.6	83.9	89.4	49	19.5	16.8
Apr. 10	41	99	50	97.7	68.4	82.9	89.5	49	29.3	21.1
Apr. 17	42	100	44	98.4	64.1	84.8	94.5	56	34.3	20.4
Apr. 24	43	97	43	94.3	50.7	76.6	88.6	54	43.6	37.9

Week ending	Week No.	Abs. Max.	Abs. Min.	Mean Max.	Mean Min.	Mean R. H.	Base Mean	Total Range	Mean Range	Mean Range below Base
May 1	44	100	31	93.6	53.9	76.1	88.8	69	39.7	34.9
May 8	45	100	40	94.3	46.4	73.8	87.8	60	48.9	41.4
May 15	46	100	45	94.4	53.6	79.2	88.3	55	40.8	34.7
May 22	47	100	55	97.3	66.9	84.8	92.4	45	30.4	25.5
May 29	48	100	60	95.6	72.0	88.6	93.2	40	23.6	21.2
June 5	49	95	57	88.7	61.6	77.9	83.6	38	27.1	22.0
June 12	50	100	54	93.1	64.0	78.9	87.5	46	29.1	23.5
June 19	51	100	50	93.6	60.1	78.0	85.3	50	33.5	25.2
June 26	52	92	47	85.6	51.3	69.6	75.0	45	34.3	23.7

TABLE B

Relative Humidity Data Station B, 10 m. above ground surface

Week ending	Week No.	Abs. Max.	Abs. Min.	Mean Max.	Mean Min.	Mean R. H.	Base Mean	Total Range	Mean Range	Mean Range Below Base
Aug. 22	8	94	58	93.1	59.8	79.0	88.7	36	33.3	28.9
Aug. 29	9	100	62	96.0	68.8	84.9	92.8	38	27.5	24.0
Sept. 5	10	100	57	100.0	69.5	90.2	95.4	43	30.5	25.0
Sept. 12	11	97	47	61.0	83.3	91.6	50.0	36	36.6	30.6
Sept. 19	12	90	35	88.0	55.3	77.5	86.2	55	32.7	30.9
Sept. 26	13	90	34	89.6	47.3	73.4	84.6	56	41.8	36.8
Oct. 3	14	97	38	95.4	56.0	81.0	92.2	59	38.4	36.2
Oct. 10	15	100	45	98.9	54.5	79.1	88.4	55.	44.3	33.9
Oct. 17	16	100	42	95.1	52.3	75.1	86.3	58	42.8	43.1
Oct. 24	17	100	40	92.0	50.0	73.6	92.2	60	42.0	32.2
Oct. 31	18	100	41	100.0	64.4	88.6	96.9	59	35.6	31.5
Nov. 7	19	97	36	93.4	46.4	73.4	87.3	61	47.0	41.0
Nov. 14	20	100	62	98.0	72.0	86.9	92.4	38	26.0	20.4
Nov. 21	21	100	50	86.3	80.1	91.8	92.6	50	16.2	12.5
Nov. 28	22									
Dec. 5	23	100	60	96.0	70.0	85.7	92.0	40	26.0	22.0
Dec. 12	24	100	47	99.1	63.4	86.0	92.7	53	35.7	29.3
Dec. 19	25	100	34	94.3	58.0	81.9	87.4	66	36.2	29.4
Dec. 26	26	100	66	96.5	82.3	93.6	93.6	34	14.2	11.3
Jan. 2	27	100	23	96.0	52.5	77.5	80.8	77	43.5	28.3
Jan. 9	28	100	49	84.1	56.0	74.2	78.2	51	28.1	22.2
Jan. 16	29	100	35	86.7	49.8	68.5	76.7	65	36.9	26.9
Jan. 23	30	100	38	92.3	57.7	79.9	85.8	62	34.6	28.1
Jan. 30	31	96	46	91.5	51.0	75.5	82.3	50	40.5	31.3
Feb. 6	32	100	48	50.7	76.5	83.0	52.0	52	42.7	32.3
Feb. 13	33	100	42	94.3	50.4	77.5	84.7	58	43.9	34.3

TABLE C

Temperature Data Station A, 0.6 m. above ground surface

Week ending	Week No.	Abs. Max.	Abs. Min.	Mean Max.	Mean Min.	Mean Temp.	Base Mean	Total Range	Mean Range	Mean Range Above Base
July 4	1	32.2	22.2					10.0		
July 11	2	33.3	23.3					10.0		
July 18	3	34.2	18.9	33.2	19.5	25.5	21.3	15.3	13.7	11.9
July 25	4	34.4	13.9	30.9	17.8	23.2	19.9	20.6	13.1	10.9
Aug. 1	5	33.3	14.4	29.4	19.4	23.7	21.5	19.0	10.0	7.9
Aug. 8	6	27.8	14.4	25.3	15.9	19.7	16.9	13.3	9.4	8.4
Aug. 15	7	27.5	11.7	23.7	15.5	18.4	17.2	15.8	8.2	6.6
Aug. 22	8	30.0	14.7	25.6	15.9	20.4	18.0	15.3	9.7	7.6
Aug. 29	9	33.3	15.0	27.7	20.3	21.6	20.9	18.3	7.4	6.8
Sept. 5	10	30.0	19.4	26.4	20.3	23.1	21.7	10.6	6.1	4.8
Sept. 12	11	29.2	11.7	23.2	15.1	18.9	17.3	17.5	8.1	5.8
Sept. 19	12	28.3	9.4	22.9	14.8	18.4	17.0	18.9	8.2	5.9
Sept. 26	13	27.5	8.1	27.0	15.1	18.1	15.7	19.4	11.9	11.3
Oct. 3	14	29.4	9.2	23.1	13.4	18.1	15.8	20.3	9.7	7.3
Oct. 10	15	23.3	2.2	17.6	6.5	12.0	8.7	21.1	11.1	8.8
Oct. 17	16	25.6	2.2	17.4	5.5	10.9	7.7	23.3	11.9	9.7
Oct. 24	17	25.6	4.4	20.2	7.8	12.8	9.9	21.1	12.4	10.3
Oct. 31	18	22.8	7.2	20.6	8.9	13.6	10.8	15.6	11.7	9.8
Nov. 7	19	18.3	− 1.7	14.8	− 0.5	6.7	2.9	20.0	15.3	11.9
Nov. 14	20	13.9	− 7.8	4.4	− 2.9	0.7	− 0.5	21.7	7.4	4.9
Nov. 21	21	17.8	− 5.0	10.5	1.4	5.8	3.8	22.8	9.1	6.7
Nov. 28	22	10.6	− 3.3	7.6	2.1	4.9	4.0	13.9	5.5	3.6
Dec. 5	23	14.4	− 3.3	7.0	0.6	3.3	2.3	17.8	6.4	4.7
Dec. 12	24	11.7	− 6.7	6.7	− 2.6	1.3	− 0.8	18.3	9.3	7.4
Dec. 19	25	12.8	−10.0	6.4	− 0.6	2.0	1.3	22.8	7.1	5.1
Dec. 26	26	8.6	− 9.4	− 1.9	− 5.8	− 4.0	− 4.8	18.1	3.8	2.9
Jan. 2	27	3.9	−12.2	− 0.7	− 8.8	− 4.9	− 6.7	16.1	8.1	6.0
Jan. 9	28	12.8	−10.0	4.5	− 5.4	− 0.8	− 4.1	22.8	9.9	8.6
Jan. 16	29	8.3	−15.8	− 1.6	−10.6	− 3.7	− 7.4	24.2	9.0	5.8
Jan. 23	30	3.1	−23.3	− 3.6	−13.0	− 9.3	−10.0	26.4	9.4	6.3
Jan. 30	31	1.7	−19.4	− 0.9	−15.7	− 9.8	−14.0	21.1	14.8	13.1
Feb. 6	32	8.6	− 7.5	5.2	− 3.3	0.3	− 1.2	16.1	8.5	6.4
Feb. 13	33	14.2	−15.0	4.7	− 4.9	− 1.4	− 3.3	29.2	9.6	7.9
Feb. 20	34	10.6	−17.8	1.2	− 9.8	− 4.9	− 7.8	28.4	11.0	9.0
Feb. 27	35	21.7	− 7.2	8.4	− 2.2	1.7	− 0.6	28.9	10.6	9.0
Mar. 6	36	11.5	− 9.2	3.7	− 6.1	− 2.1	− 4.9	20.7	9.8	8.6
Mar. 13	37	14.7	− 4.2	10.3	− 0.6	3.6	0.7	18.9	10.9	9.6
Mar. 20	38	22.8	− 0.3	16.4	3.2	8.3	5.3	23.1	13.2	11.1
Mar. 27	39	22.5	− 3.3	13.5	2.0	7.1	3.8	25.8	11.5	9.7
Apr. 3	40	15.0	− 1.1	10.6	2.7	5.7	3.8	16.1	7.9	6.8
Apr. 10	41	25.3	8.3	20.3	10.6	14.7	11.9	17.0	9.7[1]	8.4
Apr. 17	42	25.0	0.0	17.6	4.6	10.1	7.2	25.0	13.0	10.4

Week ending	Week No.	Abs. Max.	Abs. Min.	Mean Max.	Mean Min.	Mean Temp.	Base Mean	Total Range	Mean Range	Mean Range Above Base
Apr. 24	43	19.2	0.0	15.1	3.5	7.8	4.9	19.2	11.6	10.2
May 1	44	23.6	1.1	16.8	6.0	10.5	7.1	22.5	10.8	9.7
May 8	45	25.0	10.6	23.7	12.3	17.3	13.6	14.4	11.4	10.1
May 15	46	28.1	11.1	24.9	16.7	19.9	17.7	17.0	8.2	7.2
May 22	47	21.7	11.4	19.3	13.0	14.7	13.0	16.3	10.3	6.3
May 29	48	25.8	12.2	23.2	16.7	19.5	17.9	16.5	13.6	5.3
June 5	49	23.9	12.8	22.8	15.0	18.8	16.4	11.1	7.8	6.4
June 12	50	30.3	16.7	26.1	19.3	22.6	20.6	13.6	6.8	5.5
June 19	51	31.1	15.0	27.1	18.9	23.0	21.1	16.1	8.2	6.0
June 26	52	32.2	13.9	26.1	17.2	21.6	19.1	18.3	9.9	7.0

TABLE D

Temperature Data Station B, 10 m. above ground surface

Week ending	No. Week	Abs. Max.	Abs. Min.	Mean Max.	Mean Min.	Temp. Mean	Base Mean	Total Range	Mean Range	Mean Range Above Base
Aug. 1	5	33.3	13.9	30.5	20.9	24.6	21.4	19.4	9.6	9.1
Aug. 8	6	26.7	14.4	25.3	15.4	19.9	16.9	12.2	9.9	8.4
Aug. 15	7	28.3	9.4	24.3	15.6	19.6	17.1	18.9	8.7	7.2
Aug. 22	8	31.1	11.1	25.7	16.2	20.8	18.0	20.0	9.6	7.7
Aug. 29	9	30.6	15.0	23.1	19.7	23.4	21.0	15.6	8.4	7.1
Sept. 5	10	30.6	18.9	27.1	19.6	22.9	21.1	11.7	7.4	5.9
Sept. 12	11	26.7	11.7	24.8	14.8	19.4	17.1	15.0	10.1	7.7
Sept. 19	12	27.2	8.9	32.1	15.0	18.4	16.6	18.3	8.1	6.5
Sept. 26	13	31.7	7.2	25.1	13.9	19.2	17.1	24.4	11.2	7.9
Oct. 3	14	32.2	9.4	23.9	13.7	17.7	15.0	22.8	10.2	8.9
Oct. 10	15	29.4	0.6	17.8	5.8	11.8	8.7	28.9	12.1	9.1
Oct. 17	16	26.7	− 0.6	17.3	4.9	10.1	7.2	27.2	12.4	10.1
Oct. 24	17	27.8	2.2	19.1	6.8	12.1	9.0	25.6	12.2	10.1
Oct. 31	18	26.7	0.0	19.3	9.3	13.3	11.1	26.7	10.0	8.2
Nov. 7	19	18.3	− 1.7	14.2	3.3	8.2	4.8	20.0	10.9	9.4
Nov. 14	20	16.7	− 3.9	6.6	− 0.5	2.4	1.6	20.6	7.1	5.0
Nov. 21	21	18.9	− 3.9	9.7	3.4	6.5	4.9	22.8	6.3	4.8
Nov. 28	22	12.8	− 2.2	6.7	1.1	4.3	2.8	26.1	5.6	3.9
Dec. 5	23	13.9	− 2.2	7.8	2.2	4.3	3.5	16.1	5.6	4.3

TABLE E

Temperature Data—Soil Temperature 0.1 m. below surface of soil

Week Ending	Week No.	Abs. Max.	Abs. Min.	Mean Max.	Mean Min.	Mean Temp.	Extreme Range	Mean Daily Range
July 4	1	20.0	18.0	19.7	18.1	18.7	2.0	1.6
July 11	2	20.2	18.3	19.9	18.3	19.0	1.9	1.6
July 18	3	20.0	18.1	19.3	18.1	18.3	1.9	1.2
July 25	4	20.0	15.6	18.0	16.8	17.4	4.4	1.2
Aug. 1	5	20.3	16.1	19.2	17.9	17.8	4.2	1.2
Aug. 8	6	18.3	15.0	16.9	16.1	16.5	3.3	0.8
Aug. 15	7	18.3	14.7	16.6	15.8	16.3	3.6	0.8
Aug. 22	8	18.3	14.4	17.0	15.6	16.2	3.9	1.4
Aug. 29	9	19.2	14.4	17.4	16.3	16.9	4.7	1.1
Sept. 5	10	19.4	17.8	19.5	18.2	18.8	1.7	1.3
Sept. 12	11	18.3	15.3	17.2	16.1	16.7	3.1	1.1
Sept. 19	12	17.2	13.9	16.7	15.0	16.1	3.3	1.7
Sept. 26	13	17.5	12.2	15.9	14.6	15.5	5.3	1.3
Oct. 3	14	18.1	11.1	15.1	13.8	13.9	6.9	1.3
Oct. 10	15	11.7	8.6	10.4	8.8	9.5	3.1	1.6
Oct. 17	16	10.8	6.1	8.6	7.6	8.1	4.7	0.9
Oct. 24	17	12.5	7.2	10.3	9.2	5.3	5.3	1.2
Oct. 31	18	12.2	9.4	11.3	10.2	10.9	2.8	1.2
Nov. 7	19	9.7	5.6	7.8	6.2	7.1	4.2	1.6
Nov. 14	20	6.7	0.0	3.8	2.5	3.2	6.7	1.3
Nov. 21	21	1.4	0.0	1.4	0.0	0.8	1.4	1.4
Nov. 28	22	4.4	1.7	4.0	2.9	3.3	2.8	1.1
Dec. 5	23	6.1	0.6	3.4	2.3	2.9	5.6	1.2
Dec. 12	24							
Dec. 19	25	4.7	− 2.8	− 1.4	− 1.9	0.8	6.1	1.5
Dec. 26	26	0.8	− 1.4	− 1.4	− 1.9	− 1.6	3.6	0.5
Jan. 2	27	− 2.8	− 3.9	− 2.8	− 3.1	− 2.9	1.1	9.3
Jan. 9	28	− 2.8	− 3.3	− 3.1	− 3.3	− 3.2	0.6	0.2
Jan. 16	29	− 2.8	− 4.7	− 3.4	− 3.8	− 3.6	1.9	0.4
Jan. 23	30	− 5.8	− 7.2	− 6.3	− 6.7	− 6.5	1.4	0.4
Jan. 30	31	− 4.2	− 5.8	− 4.5	− 4.9	− 4.7	1.7	0.4
Feb. 6	32	− 3.6	− 5.3	− 4.1	− 4.2	− 4.1	1.7	0.1
Feb. 13	33	− 3.3	− 5.0	− 3.6	− 4.1	− 3.8	1.7	0.4
Feb. 20	34	− 3.3	− 5.8	− 4.4	− 4.8	− 4.6	2.5	0.4
Feb. 27	35	− 3.3	− 3.9	− 3.4	− 3.5	− 3.45	0.6	0.1
Mar. 6	36	− 2.6	− 3.4	− 2.8	− 3.3	− 3.0	0.8	0.5
Mar. 13	37	3.9	− 2.8	0.0	− 1.0	− 0.5	6.7	1.0
Mar. 20	38	6.7	1.7	5.7	2.2	4.4	5.0	3.5
Mar. 27	39	8.3	− 0.5	4.7	2.9	3.7	8.8	1.8
Apr. 3	40	6.3	0.1	4.4	2.9	3.7	6.2	1.5
Apr. 10	41	12.8	5.3	10.0	9.1	9.8	7.5	0.9
Apr. 17	42	13.8	5.8	10.3	7.9	9.2	8.0	2.4
Apr. 24	43	12.5	3.9	8.2	5.8	7.0	8.6	2.4

Week Ending	Week No.	Abs. Max.	Abs. Min.	Mean Max.	Mean Min.	Mean Temp.	Extreme Range	Mean Daily Range
May 1	44	10.3	4.7	8.7	6.8	7.8	5.6	1.9
May 8	45	14.3	11.3	13.4	11.8	12.6	3.0	1.6
May 15	46	14.4	10.6	14.1	12.8	13.5	3.8	1.3
May 22	47	12.7	9.6	11.7	10.9	11.3	3.1	0.8
May 29	48	15.0	12.3	14.4	13.3	13.9	3.3	1.1
June 5	49	15.0	11.9	13.9	12.7	13.3	3.1	1.2
June 12	50	18.6	13.9	17.3	15.8	16.6	4.7	1.5
June 19	51	19.4	15.4	17.8	16.3	17.1	4.0	1.5
June 26	52	17.7	13.6	16.3	14.4	15.3	4.1	1.9

TABLE F

Evaporation Data, as Obtained from Porous Cup Atmometers

Station Number		1	2	3	4	5	6	7	8	9	10	11
Height (m)		1.0	0.15	1.5	1.5	2.5	0.15	0.15	6.0	10.0	12.0 15.0†	0.15
Date	Week	Average daily evaporation in cc. (reduced to standard)										
June 30		*	*	*	*	*	*	*				
July 2		11.1										
July 4	1	12.0	7.5	12.6	11.0	13.7	2.4	20.9				
July 11	2	13.6	8.5	14.3	14.3	14.9	7.6	20.7				
July 18	3	19.1	13.0	19.4	19.4	20.2	7.6	24.8	*			
July 25	4	14.8	9.7	15.3	15.3	16.2	10.2	24.9		*		
Aug. 1	5	13.9	9.5	15.2	14.6	15.1	8.6	‡	19.6	15.4		
Aug. 8	6	7.9	5.0	8.3	8.6	9.0	2.8		10.7	10.9	*	*
Aug. 15	7	6.6	4.7	7.7	7.8	7.8	2.6		9.7	10.8	12.2	8.8
Aug. 22	8	8.1	5.0	8.1	8.2	9.0	2.8		10.1	10.1	11.2	8.1
Aug. 29	9	4.6	2.8	4.6	4.8	5.7	1.3		7.7	6.9	6.3	6.2
Sept. 5	10	4.4	2.9	5.5	5.4	5.7	1.7		4.6	8.9	¶	6.5
Sept. 12	11	4.3	2.5	4.6	4.4	5.0	1.3			6.9	10.1	6.3
Sept. 19	12	5.0	3.9	5.9	6.0	6.6	1.6		6.7	7.7	13.9	5.1
Sept. 26	13	7.6	4.2	8.4	7.7	8.9	3.3		10.6	8.7	12.0	5.1
Oct. 3	14	7.0	4.8	8.8	7.9	8.6	3.3		9.3	9.2	14.1	6.3
Oct. 10	15	8.6	5.5	9.9	9.0	9.6	5.0		9.4	9.3	8.7	6.7
Oct. 17	16	11.6										
Oct. 24	17	15.2										
Oct. 31	18	11.0										
Nov. 7	19	13.6										
Nov. 14		frozen										
Apr. 17		*		*		*						

Station Number		1	2	3	4	5	6	7	8	9	10	11
Height (m)		1.0	0.15	1.5	1.5	2.5	0.15	0.15	6.0	10.0	12.0 15.0†	0.15
Date	Week	Average daily evaporation in cc. (reduced to standard)										
Apr. 24	43	12.6		12.3		11.7						
May 1	44	13.2	*	13.5		16.9						
May 8	45	17.3	11.5	17.3		20.2						
May 15	46	10.3	6.2	10.0		10.6						
May 22	47		3.4	7.5		8.0						
May 29	48	6.7	4.1	6.8		9.0						
June 5	49	10.6	5.9	10.7		13.3						
June 12	50		5.1	12.3		12.9						
June 19	51	12.3	7.2	12.7		14.7						
June 26	52	9.7	6.2	9.9		11.7						
July 3	53	11.5	7.1	11.3		14.0						

* Atmometer set up on this date. First reading includes evaporation beginning on this date.

† Atmometer changed to another tree at greater height on September 5.

‡ Atmometer stolen and observations at this station discontinued. See Station 11.

¶ Atmometer moved on this date to a height of 15 m. in another tree.

Location of Stations:

1—Top of instrument shelter.
2—On ground under shrubs.
3—South side of tree trunk.
4—North side of tree trunk.
5—Suspended under leafy maple branch.
6—In hollow stump.
7—At west edge of woods, short grass.
8—In tree.
9—In tree.
10—At level of tree tops, first at 12 m, later at 15 m.
11—At east edge of woods, tall grass.

TABLE G

Diurnal Variations in Light Intensity as Determined by the Macbeth Illuminometer
August 29-30, 1921

Time	Light Intensity in Meter-Candles		
	In Forest		In Forest Glade
	Ground Level Under Herbage	1.25 m. above Ground Level	1.25 m. above Ground Level
Aug. 30			
7:20 a.m.			1140
7:50-8:10 a.m.	102	170	44940
9:00-9:10	155	355	77400
10:00-10:10	113	705	82220
12:30-12:40 p.m.		1170	96650
1:00	378		
Aug. 29			
2:40-3:10 p.m.	184	430	83660
4:05-4:25	107	210	
4:45-5:15	43	95	17680
5:50-5:55		14	2570
6:00-6:15			1570

TABLE H

Animal Population of the Lower Strata of University Woods, July 1921 to June 1922

Week Ending	Week Number	Soil Stratum		Leaf Stratum		Herb Stratum		Shrub Stratum		Total	Per Acre (thousands)	Per Hectare (thousands)
		Number of Samples	Average per Sample	Number of Samples	Average per Sample	Number of Samples	Average per Sample	Number of Samples	Average per Sample			
July 4	1	1	11	2	24.5	3	9	3	0.6	45.1	496	1218
July 11	2	1	16	1	20	6	13.5		2	51.5	566	1391
July 18	3	1	10	1	14	3	15	3	4.8	43.8	481	1183
July 25	4	1	15	2	5	3	8.4		4.2	32.6	359	980
Aug. 1	5	3	14.7	1	11		11.5		3.9	41.1	452	1109
Aug. 8	6	2	14.5	1	12	3	14	3	3.6	44.1	485	1191
Aug. 15	7											
Aug. 22	8	1	18	1	15	3	8	2	4.5	44.5	490	1201
Aug. 29	9	1	19	1	21	5	5.8	1	1.	46.8	515	1264
Sept. 5	10		14.5		32	5	18.2	5	3.4	68.1	749	1839
Sept. 12	11	1	10	1	43	1	22	1	15	90	990	2437

Week Ending	Week Number	Soil Stratum		Leaf Stratum		Herb Stratum		Shrub Stratum		Total	Per Acre (thousands)	Per Hectare (thousands)
		Number of Samples	Average per Sample	Number of Samples	Average per Sample	Number of Samples	Average per Sample	Number of Samples	Average per Sample			
Sept. 19	12	1	17	1	24	1	30	1	15	86	946	2322
Sept. 26	13		15		60	2	54	2	78.5	207.5	2283	5603
Oct. 3	14		13	1	133	1	283	1	69	498	5480	13446
Oct. 10	15											
Oct. 17	16		7	1	49	1	128	1	24	208	2288	5616
Oct. 24	17											
Oct. 31	18	1	27	1	146	1	25	1	14	212	2352	5734
Nov. 7	19	1	12	1	125	1	23	1	5	169	1859	4773
Nov. 14	20		13	1	85		20		4.5	121.5	1337	3280
Nov. 21	21	1	14	1	54	1	16	1	4	82	902	2214
Nov. 28	22	1	1	1	33	1	37	1	9	93	1023	2511
Dec. 5	23	1	13	1	36	1	11	1	0	48	528	1296
Dec. 12	24	1	5	1	51	1	2	1	0	66	726	1782
Dec. 19	25	1	5	1	22	1	16	1	0	43	473	1161
Dec. 26	26											
Jan. 2	27	1	3	1	34	1	8	1	0	45	495	1215
Jan. 9	28	2	5.5	1	58	1	4	1	0	67.5	743	1823
Jan. 16	29	1	3	1	15	1	0	1	0	18	198	486
Jan. 23	30			1	22							
Jan. 30	31			1	22							
Feb. 6	32	1	7	1	90	1	3	1	0	100	1100	2700
Feb. 13	33	1	6	1	10	1	0	1	0	17	187	459
Feb. 20	34	1	7	1	16	1	0	1	0	23	258	621
Feb. 27	35	1	7	1	29	1	0	1	0	36	396	972
Mar. 6	36	1	10	1	7	1	4	1	0	21	231	567
Mar. 13	37	1	4	1	13	1	12	1	3	32	352	864
Mar. 20	38			1	23							
Mar. 27	39	1	14	1	74	1	6	1	1	95	1045	2565
Apr. 3	40	1	5	1	28	1	11	1	2	46	506	1242
Apr. 10	41	1	6	1	68	1	39	1	23	136	1496	3772
Apr. 17	42											
Apr. 24	43	1	0	1	34	1	3	1	163	200	2200	5400
May 1	44	1	13	1	39	1	51	1	398	501	5511	13527
May 8	45	1	1	1	26	1	400	1	64	491	5501	13257
May 15	46	1	22	1	9	1	52	1	51	134	1474	3618
May 22	47			1	9	1	4	1	63			
May 29	48	1	8	1	7	1	34	1	42	91	1001	2457
June 5	49	1	1	1	2	1.5	24	1.5	8	35	385	955
June 12	50	1	10	1	6	1	54	1	25	95	1045	2565
June 19	51	1	10	1	5	1	40	1	31	86	946	2322
June 26	52	1	0	1	0	1	55	1	32	87	957	2349
July 3	1	1	14	1	5	1	55	1	20	94	1034	2538

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